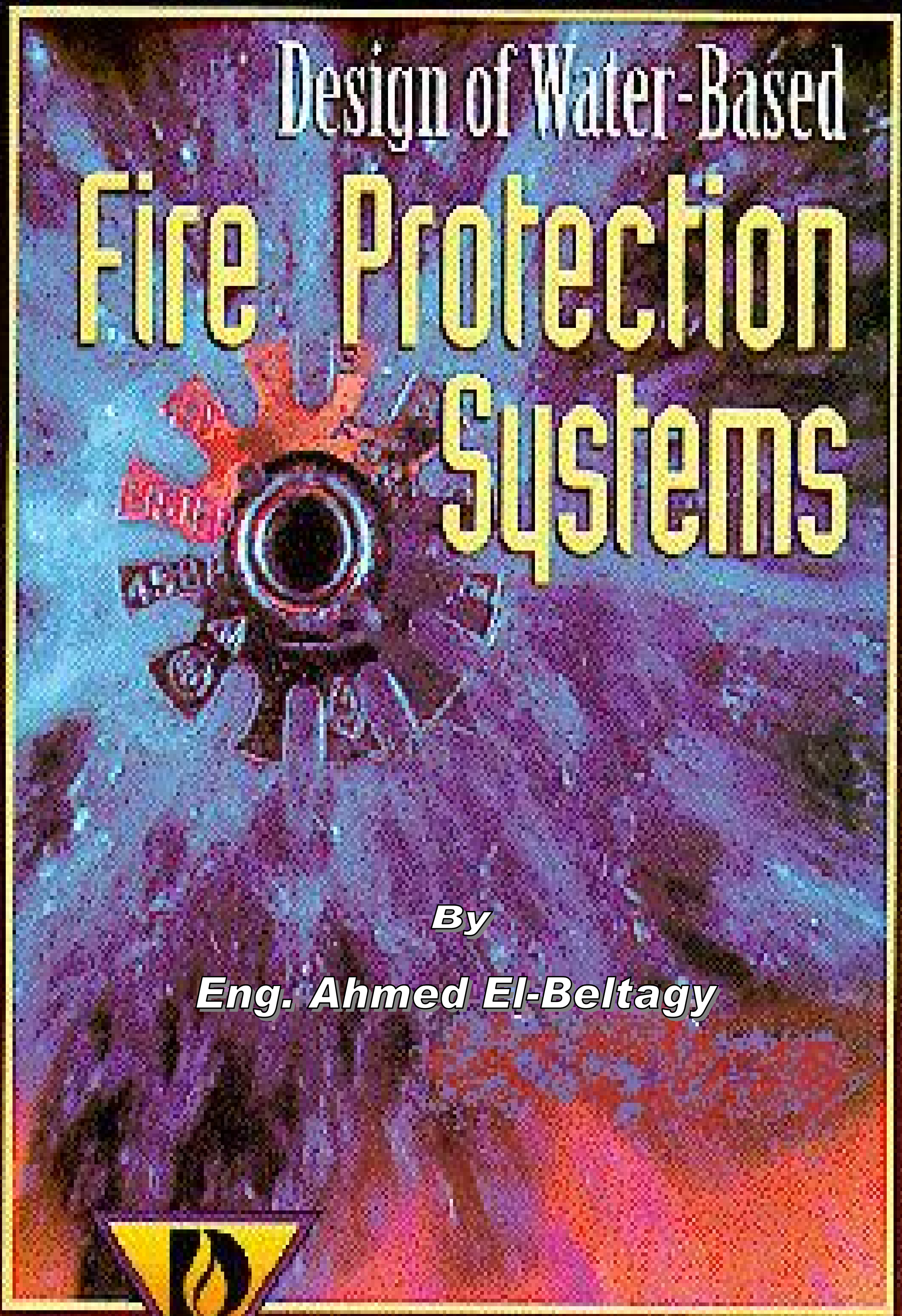
## Design of Water-Based

# Fire Protection Systems



By

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DISK INCLUDED!

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## PART (I)
## STAND PIPE SYSTEM DESIGN

# PART (II)

# SPRINKLER SYSTEM DESIGN

# Part 1
# Stand Pipe System Design

## 1. Sytem Classes ( NFPA 14 - 5.3 )

### a) Class I Systems.

It shall be provided with **21/2-in**. hose connections in the following **locations**:-

(a) At each intermediate landing between floor levels in every required exit stairway.
*Exception: Hose connections shall be permitted to be located at the main floor landings in exit stairways where approved by the authority having jurisdiction.*

(b) On each side of the wall adjacent to the exit openings of horizontal exits.

(c) In each exit passageway at the entrance from the building areas into the passageway.

(d) In covered mall buildings, at the entrance to each exit passageway or exit corridor, and at exterior public entrances to the mall.

(e) At the highest landing of stairways with stairway access to a roof, and on the roof where stairways do not access the roof. An additional 21/2-in. hose connection shall be provided at the hydraulically most remote riser to facilitate testing of the system.

(f) * Where the most remote portion of a nonsprinklered floor or story is located in excess of 150 ft (45.7 m) of travel distance from a required exit containing or adjacent to a hose connection, or the most remote portion of a sprinklered floor or story is located in excess of 200 ft (61 m) of travel distance from a required exit containing or adjacent to a hose connection, additional hose connections shall be provided, in approved locations, where required by the local fire department or the authority having jurisdiction.

### Class II Systems.

Class II systems shall be provided with **11/2-in**. hose stations so that all portions of each floor level of the building are within 130 ft (39.7 m) of a hose connection provided with 11/2-in. hose or within 120 ft (36.6 m) of a hose connection provided with less than 11/2-in. hose. Distances shall be measured along a path of travel originating at the hose connection.

### Class III Systems.

Class III systems shall be provided with hose connections as required for both Class I and Class II systems.

## 2. Stand Pipe Number and Connections ( NFPA 14 - 5.4&5.5 )

- Separate standpipes shall be provided in each required exit stairway.
- Where two or more standpipes are installed in the same building or section of building, they shall be interconnected at the bottom.
- Where standpipes are supplied by tanks located at the top of the building or zone, they also shall be interconnected at the top; in such cases, check valves shall be installed at the base of each standpipe to prevent circulation.

## 3. Pipe Sizing ( NFPA 14 - 5.6 )

- Pipes can be sized by hydraulic calculations or according to pipe Schedule Sizing.
- Class I and Class III standpipes shall be at least 4 in. in size.
- Standpipes that are part of a combined system shall be at least 6 in. in size.
  Exception: In fully sprinklered buildings having a combined standpipe system that is hydraulically calculated, the minimum standpipe size is 4 in.
- Pipe Schedule Sizing.

| Total Accumulated Flow | | Total Distance of Piping from Farthest Outlet | | |
|---|---|---|---|---|
| **gpm** | **L/min** | **<50 ft (<15.2 m)** | **50-100 ft(15.2-30.5 m)** | **>100 ft(>30.5 m)** |
| 100 | 379 | 2 | 21/2 | 3 |
| 101-500 | 382-1893 | 4 | 4 | 6 |
| 501-750 | 1896-2839 | 5 | 5 | 6 |
| 751-1250 | 2843-4731 | 6 | 6 | 6 |
| 1251 and over | 4735 | 8 | 8 | 8 |
| For SI units, 1 gpm = 3.785 L/min; 1 ft = 0.3048 m. | | | | |

**(NFPA 14 - 5.7) Pipe Schedule - Standpipes and Supply Piping Minimum Nominal Pipe Sizes in Inches**

## 4. Flow Rate and Pressure Requirements ( NFPA 14 - 5.7 & 5.8 & 5.9 )

### 1. Flow Rate:-

- For Class I & Class III systems the minimum flow rate for the hydraulically most remote standpipe shall be **500 gpm**
- The minimum flow rate for additional standpipes shall be **250 gpm** per standpipe.
  Exception: When the floor area exceeds 80,000 ft2 (7432 m2), the second most remote standpipe shall be designed to accommodate **500 gpm**.
- Total system required discharge not to exceed 1250 gpm.
- For Class II systems, the minimum flow rate for the hydraulically most remote standpipe shall be **100 gpm**

### 2. Pressure:-

- Minimum residual at the outlet of the hydraulically most remote **21/2-in** is **100 psi** .
- Minimum residual at the outlet of the hydraulically most remote **11/2-in** is **65 psi**.

  Exception No. 1: Where the authority having jurisdiction permits pressures lower than **100 psi** for 21/2-in. hose connections, based on suppression tactics, the pressure shall be permitted to be reduced to not less than **65 psi**
  Exception No. 2: In other than high-rise buildings, the authority having jurisdiction shall be allowed to reduce the minimum pressure requirements of this section if the building is protected throughout by an approved automatic sprinkler system.

- Residual pressure range at the outlet of the hydraulically most remote **21/2-in** is **(100psi:175psi)** .
- Residual pressure range at the outlet of the hydraulically most remote **11/2-in** available for occupant use is **(65psi:100psi)**

- Where the static pressure at a hose connection exceeds the pre-mentioned values, an approved pressure-regulating device shall be provided to limit static and residual pressures at the outlet of the hose connection to 100 psi for 11/2-in. hose connections available for occupant use and 175 psi for other hose connections. The pressure on the inlet side of the pressure-regulating device shall not exceed the device's rated working pressure.

## 5. Hydraulic Calculations Procedures ( NFPA 14 - 5.9)

### 1. Class I & III Systems (NFPA 14 - 5.9.1.2):-

- Each hose connection require **250 gpm**.
- Use **2** connections at the most remote standpipe, that requires **500 gpm**.
- Use **1** connection at each additional stand pipe in the system and that requires **250 gpm**.
- The total flow not to exceed **1250 gpm**.
- The pressure required at the most remote hose connection is **100 psi** or **65 psi** if approved by Civil Defense authority (NFPA 14 - 5.7).
- The pipe sizing may be considered as 3" for 1 hose, 4" for 2 hoses and 6" for more than 2 hoses.
- The Required Pump Head is $H = H_{ELEVATION} + H_{RESIDULE} + H_{FRICTION}$

### 2. Class II Systems (NFPA 14 - 5.9.2.2):-

- Hydraulic calculations and pipe sizes for each standpipe shall be based on providing **100 gpm and 65 psi** at the hydraulically most remote hose connection on the standpipe.
- Common supply piping serving multiple standpipes shall be calculated and sized to provide 100 gpm (Maximum of 3 in ).
- The Required Pump Head is $H = H_{ELEVATION} + H_{RESIDULE} + H_{FRICTION}$

### 3. Combined Systems (NFPA 14 - 5.9.1.3):-

- When the system is served throughout both automatic sprinkler system and hose system, Hydraulic calculation shall be done for both systems separately.
- The larger of the two values shall be provided.
- The pre-mentioned system demand (Maximum of **1250 gpm**) shall be permitted to serve the sprinkler system. A separate sprinkler demand shall not be required.
- For a combined system in a building equipped with **partial** automatic sprinkler protection, the pre-mentioned flow rate shall be increased by an amount equal to the hydraulically calculated sprinkler demand or **150 gpm** for **light hazard** occupancies, or by **500 gpm** for **ordinary hazard** occupancies, whichever is **less**.

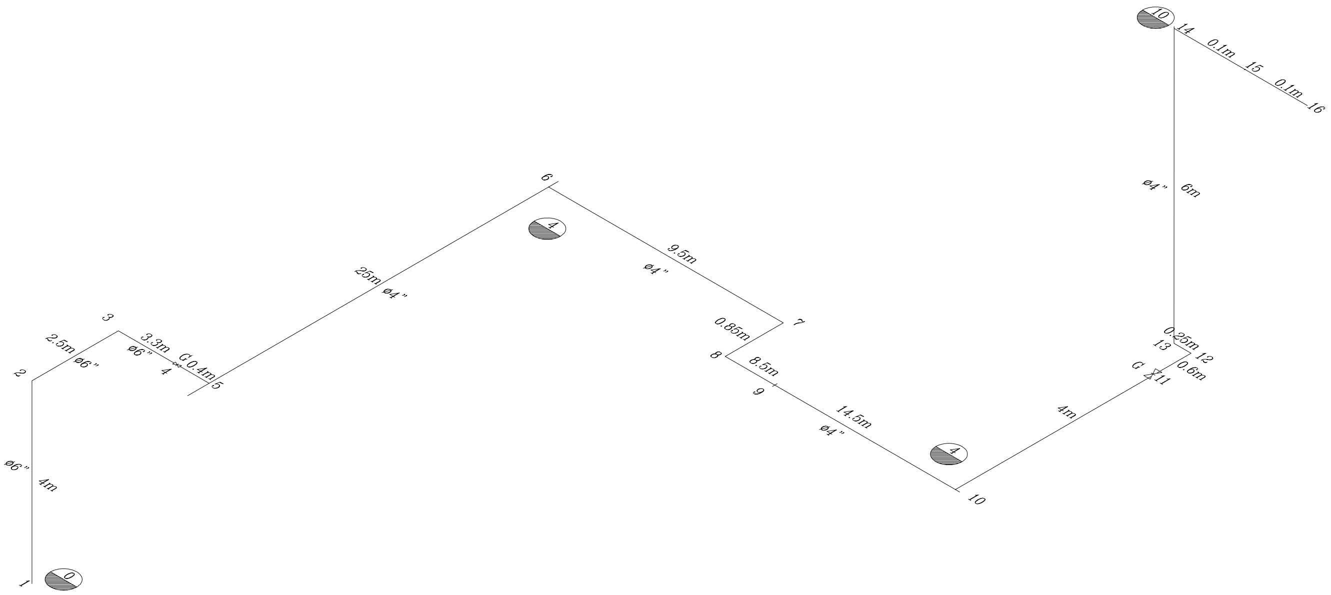
# Hydraulic Calculations Example :-

The example we have here is a VolksWagen car maintenance center.

1. **Hydraulic Calculations Parameters:**

| | |
|---|---|
| Hose System : | Class III |
| System type : | Combined |
| Minimum Residual Pressure : | 65 psi |
| Hose Discharge : | 250 gpm |
| Total No of Hoses per path : | 2 |

2. **System Schematic Diagram:-**



## 3. Hydraulic Calculations Sheet:-

| Section | Flow [gpm] | Pipe Size [in] | Fittings& Devices | Pipe Equiv. Length [ft] | Friction loss [psi/ft] | Required [psi] | Elev [m] | Notes. |
|---|---|---|---|---|---|---|---|---|
| Hose No16 | q 250 | 2.469" | | LGTH. 0.328 | 0.215 | PT. 65 | | |
| From. 16 | Q 250 | | | FTG. | | PF. +0.071 | | |
| To. 15 | | | | TOT. 0.328 | | PE. | | |
| Hose No. | q 250 | 3.068" | Tee | LGTH. 0.328 | 0.075 | PT. 65.071 | | |
| From. 15 | Q 250 | | | FTG. 15 | | PF. +1.15 | | |
| To. 14 | | | | TOT. 15.328 | | PE. | | |
| Hose No. | q 250 | 4.026" | Tee | LGTH. 19.685 | 0.02 | PT. 66.221 | | |
| From. 14 | Q 250 | | | FTG. 20 | | PF. +0.794 | | |
| To. 13 | | | | TOT. 39.685 | | PE. +8.534 | +6 | |
| Hose No. | q 250 | 4.026" | Elbow 90 | LGTH. 0.82 | 0.02 | PT. 75.549 | | |
| From. 13 | Q 250 | | | FTG. 10 | | PF. +0.216 | | |
| To. 12 | | | | TOT. 10.82 | | PE. | | |
| Hose No. | q 250 | 4.026" | Gate Valve | LGTH. 1.97 | 0.02 | PT. 75.765 | | |
| From. 12 | Q 250 | | | FTG. 2 | | PF. +0.079 | | |
| To. 11 | | | | TOT. 3.97 | | PE. | | |
| Hose No. | q 250 | 4.026" | Tee | LGTH. 13.12 | 0.02 | PT. 75.844 | | |
| From. 11 | Q 250 | | | FTG. 20 | | PF. +0.662 | | |
| To. 10 | | | | TOT. 33.12 | | PE. | | |
| Hose No. | q 250 | 4.026" | | LGTH. 47.57 | 0.02 | PT. 76.506 | | |
| From. 10 | Q 250 | | | FTG. | | PF. +0.951 | | |
| To. 9 | | | | TOT. 47.57 | | PE. | | |
| Hose No. | q 500 | 4.026" | Elbow 90 | LGTH. 27.89 | 0.072 | PT. 77.457 | | |
| From. 9 | Q 500 | | | FTG. 10 | | PF. +2.728 | | |
| To. 8 | | | | TOT. 37.89 | | PE. | | |
| Hose No. | q 500 | 4.026" | Elbow 90 | LGTH. 2.79 | 0.072 | PT. 80.185 | | |
| From. 8 | Q 500 | | | FTG. 10 | | PF. +0.921 | | |
| To. 7 | | | | TOT. 12.79 | | PE. | | |
| Hose No. | q 500 | 4.026" | Tee | LGTH. 31.17 | 0.072 | PT. 81.106 | | |
| From. 7 | Q 500 | | | FTG. 20 | | PF. +3.684 | | |
| To. 6 | | | | TOT. 51.17 | | PE. | | |
| Hose No. | q 500 | 4.026" | Tee | LGTH. 82.02 | 0.072 | PT. 84.79 | | |
| From. 6 | Q 500 | | | FTG. 20 | | PF. +7.345 | | |
| To. 5 | | | | TOT. 102.02 | | PE. | | |
| Hose No. | q 500 | 4.026" | Gate Valve | LGTH. 1.31 | 0.072 | PT. 92.135 | | |
| From. 5 | Q 500 | | | FTG. 2 | | PF. +0.238 | | |
| To. 4 | | | | TOT. 3.31 | | PE. | | |
| Hose No. | q 500 | 6.065" | Elbow 90 | LGTH. 10.83 | 0.01 | PT. 92.373 | | |
| From. 4 | Q 500 | | | FTG. 14 | | PF. +0.248 | | |
| To. 3 | | | | TOT. 24.83 | | PE. | | |
| Hose No. | q 500 | 6.065" | Elbow 90 | LGTH. 8.2 | 0.01 | PT. 92.621 | | |
| From. 3 | Q 500 | | | FTG. 14 | | PF. +0.222 | | |
| To. 2 | | | | TOT. 22.2 | | PE. | | |
| Hose No. | q 500 | 6.065" | | LGTH. 13.12 | 0.01 | PT. 92.843 | | |
| From. 2 | Q 500 | | | FTG. | | PF. +0.131 | | |
| To. 1 | | | | TOT. 13.12 | | PE. + 5.69 | +4 | |
| | Q 500 gpm | | | | PT. | 98.664 psi | | |

# Part 2
# Sprinkler System Design

## 1- System Type (NFPA 13 – 3.4)

- Fire protection system can be classified according to :-

- Actuation System
- System Shape

### 1- According to Actuation Systems

a- Wet Pipe Sprinkler System.
System is full of water and actuated through automatic sprinklers.

b- Deluge Sprinkler System.
**Open sprinklers** are used and actuation is through normally closed **(Deluge Valve)** that is opened by the operation of a detection system installed in the same areas as the sprinklers.
Note:- Volume between valve and sprinkler is full of air.

c- Preaction Sprinkler System.
**Automatic sprinklers** are used and actuation is through normally closed **(Deluge Valve)** that is opened by the operation of a detection system installed in the same areas as the sprinklers.
Note:- -Volume between valve and sprinkler is full of air that might or might not be under pressure.
-Preaction system provides double control on fire protection system.

d- Dry Pipe Sprinkler System.
**Automatic sprinklers** and **dry pipe valve** are used and actuation is through the following criteria :-

- Piping system between sprinklers and valve contains air or nitrogen under pressure.
- Water on the other side of valve is under pressure and the valve is balanced.
- After sprinklers opening the water pressure opens the dry pipe valve and water flows out to the opened sprinklers.

e- Combined Dry Pipe-Preaction Sprinkler System.
**Automatic sprinklers** and **dry pipe valves** and **detection system** and **air exhaust valves** are used for actuation in the following criteria:-

- Piping contains air under pressure.
- Detection system actuates tripping devices that open dry pipe valves.
- Detection system also opens air exhaust valves at the end of the feed main, which usually precedes the opening of sprinklers.
- Water flows in system towards opened sprinklers.

Note:- Combined system provides fast response and double control on fire protection system.

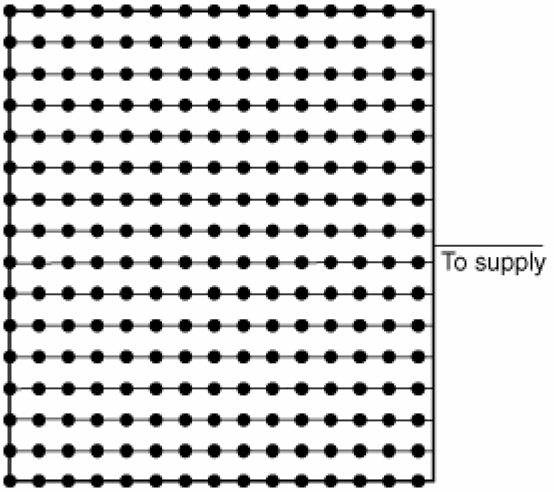
| No. | System Type | Additional Water Volume |
|---|---|---|
| 1 | Wet pipe system | Flow requirement of the hydraulically most remote system demand for **1 minute** |
| 2 | Preaction system<br>Deluge system<br>Dry pipe system | Flow requirement of the hydraulically most remote system demand for **1 minute** of system demand **plus** the volume needed to **fill all dry piping** |

**(NFPA 13 - Table 17.7.2.1) Required Water Supply**

## 2- According to System Shape.

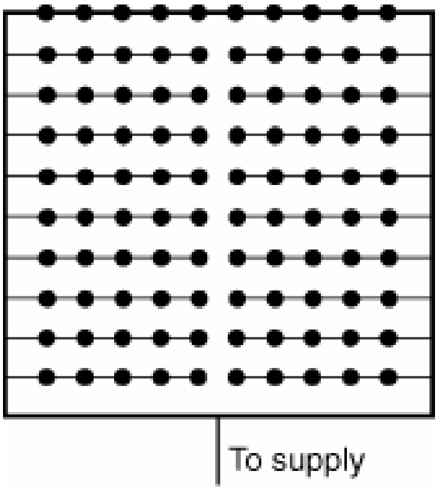
a- Tree Sprinkler System.
It is the normal design system and it consists of main pipe line with branches on both LHS and RHS.

b- Gridded Sprinkler System.
A sprinkler system in which parallel cross mains are connected by multiple branch lines. An operating sprinkler will receive water from both ends of its branch line while other branch lines help transfer water between cross mains.
Note:- System allows minimizing pipes sizes.




**(NFPA 13 - FIGURE A.3.4.6) Gridded System.**

c- Looped Sprinkler System.
A sprinkler system in which multiple cross mains are tied together so as to provide **two** paths for water to flow to an operating sprinkler and branch lines are **not tied together**.




**(NFPA 13 - FIGURE A.3.4.6) Looped System.**

## 2- System Hazard (NFPA 13 – A.5)

### Classification of Occupancies.

Occupancy classifications shall relate to sprinkler design, installation, and water supply requirements only.

### a- Light Hazard Occupancies.

Light hazard occupancies shall be defined as occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.

**Light hazard occupancies include occupancies having uses and conditions similar to the following:**

-Churches
-Clubs
-Eaves and overhangs, if of combustible construction with no combustibles beneath
-Educational
-Hospitals
-Institutional
-Libraries, except large stack rooms
-Museums
-Nursing or convalescent homes
-Offices, including data processing
-Residential
-Restaurant seating areas
-Theaters and auditoriums, excluding stages and prosceniums
-Unused attics

## b- Ordinary Hazard Occupancies.

### b.1 Ordinary Hazard (Group 1).

Ordinary hazard (Group 1) occupancies shall be defined as occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles **do not exceed 8 ft (2.4 m),** and fires with moderate rates of heat release are expected.

**Ordinary hazard occupancies (Group 1) include occupancies having uses and conditions similar to the following:**

-Automobile parking and showrooms
-Bakeries
-Beverage manufacturing
-Canneries
-Dairy products manufacturing and processing
-Electronic plants
-Glass and glass products manufacturing
-Laundries
-Restaurant service areas

### b.2 Ordinary Hazard (Group 2).

Ordinary hazard (Group 2) occupancies shall be defined as occupancies or portions of other occupancies where the quantity and combustibility of contents are moderate to high, stockpiles **do not exceed 12 ft (3.7 m),** and fires with moderate to high rates of heat release are expected.

**Ordinary hazard occupancies (Group 2) include occupancies having uses and conditions similar to the following:**

-Cereal mills
-Chemical plants — ordinary
-Confectionery products
-Distilleries
-Dry cleaners
-Feed mills
-Horse stables
-Leather goods manufacturing
-Libraries — large stack room areas
-Machine shops
-Metal working
-Mercantile
-Paper and pulp mills
-Paper process plants
-Piers and wharves
-Post offices
-Printing and publishing
-Repair garages
-Resin application area
-Stages
-Textile manufacturing
-Tire manufacturing
-Tobacco products manufacturing
-Wood machining
-Wood product assembly

## c- Extra Hazard Occupancies.

### c.1 Extra Hazard (Group 1).

Extra hazard (Group 1) occupancies shall be defined as occupancies or portions of other occupancies where the quantity and combustibility of contents are very high and dust, lint, or other materials are present, introducing the probability of **rapidly developing fires** with high rates of heat release but with little or **no combustible or flammable liquids**.

**Extra hazard occupancies (Group 1) include occupancies having uses and conditions similar to the following:**

-Aircraft hangars (except as governed by NFPA 409, Standard on Aircraft Hangars)
-Combustible hydraulic fluid use areas
-Die casting
-Metal extruding
-Plywood and particle board manufacturing
-Printing [using inks having flash points below 100°F (38°C)]
-Rubber reclaiming, compounding, drying, milling, vulcanizing
-Saw mills
-Textile picking, opening, blending, garnetting, or carding, combining of cotton, synthetics, --
-wool shoddy, or burlap
-Upholstering with plastic foams

### c.2 Extra Hazard (Group 2).

Extra hazard (Group 2) occupancies shall be defined as occupancies or portions of other occupancies with moderate to **substantial amounts of flammable or combustible liquids** or occupancies **where shielding of combustibles is extensive**.

**Extra hazard occupancies (Group 2) include occupancies having uses and conditions similar to the following:**

-Asphalt saturating
-Flammable liquids spraying
-Flow coating
-Manufactured home or modular building assemblies (where finished enclosure is present and has combustible interiors)
-Open oil quenching
-Plastics processing
-Solvent cleaning
-Varnish and paint dipping

## 3- Sprinkler Types. (NFPA 13 – 3.6.2)

In general we use the standard spray sprinkler as follows:-

- We use the upright standard spray sprinkler as it's the lowest cost.
- In case of suspended ceiling or any other circumstances that require a pendent sprinkler we use the pendent standard spray sprinkler.
- We use sidewall sprinklers if needed.

We use any type of the following sprinklers if needed in certain application.

The following sprinklers are defined according to design and performance characteristics.

1-) Standard Spray Sprinkler.

1st) The upright or pendent Standard Spray Sprinklers (NFPA 13 – 8.6):-

**General Sprinklers Spacing Notes:-**

- In any case, the maximum area of coverage of a sprinkler shall not exceed **225 $ft^2$ (21 $m^2$)**.
- The distance from sprinklers to walls shall not exceed **one-half** of the allowable distance between sprinklers.
- The distance from the wall to the sprinkler shall be measured perpendicular to the wall.
- In small rooms, sprinklers shall be permitted to be located not more than **9 ft (2.7 m)** from any single wall.
- Sprinklers shall be located a minimum of 4 in. (102 mm) from a wall.
- The maximum horizontal distance between a sprinkler and any point of floor area protected by that sprinkler shall not exceed **0.75 times** the allowable distance permitted between sprinklers.
- Sprinklers shall be spaced not less than **6 ft (1.8 m)** on center.

**Ceiling Pockets (NFPA13 - 8.6.7).**

- Sprinklers shall be required in all ceiling pockets unless the following conditions are met.

1- The total volume of the unprotected ceiling pocket does not exceed 1000 ft3.
2- The depth of the unprotected pocket does not exceed 36 in.
3- The entire floor under the unprotected ceiling pocket is protected by the sprinklers at the lower ceiling elevation.
4- Each unprotected ceiling pocket is separated from any adjacent unprotected ceiling pocket by a minimum 10 ft horizontal distance.
5- The unprotected ceiling pocket is constructed of noncombustible or limited combustible construction.
6- Skylights not exceeding 32 ft2 shall be permitted to have a plastic cover.
7- Quick response sprinklers are utilized throughout the compartment.

| Construction Type | System Type | Protection Area | | Spacing (maximum) | |
|---|---|---|---|---|---|
| | | ft² | m² | ft | m |
| Noncombustible obstructed and unobstructed and combustible unobstructed with members 3 ft or more on center | Pipe schedule | 200 | 18.6 | 15 | 4.6 |
| Noncombustible obstructed and unobstructed and combustible unobstructed with members 3 ft or more on center | Hydraulically calculated | 225 | 20.9 | 15 | 4.6 |
| Combustible obstructed with members 3 ft or more on center | All | 168 | 15.6 | 15 | 4.6 |
| Combustible obstructed or unobstructed with members less than 3 ft on center | All | 130 | 12.1 | 15 | 4.6 |
| Unoccupied attics having combustible wood joist or wood truss construction with members less than 3 ft on center with slopes having a pitch of 4 in 12 or greater | All | 120 | 11.1 | 8* × 15 (minimum psi) 10* × 12 (minimum 20 psi) | 2.4* × 4.6 (minimum 0.48 bar) 3* × 3.7 (minimum 1.34 bar) |
| *The smaller dimension shall be measured perpendicular to the slope. | | | | | |

**(NFPA 13 - Table 8.6.2.2.1(a)) Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Light Hazard**

| Construction Type | System Type | Protection Area | | Spacing (maximum) | |
|---|---|---|---|---|---|
| | | ft² | m² | ft | m |
| All | All | 130 | 12.1 | 15 | 4.6 |

**(NFPA13 - Table 8.6.2.2.1(b)) Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Ordinary Hazard**

| Construction Type | System Type | Protection Area | | Spacing (maximum) | |
|---|---|---|---|---|---|
| | | ft² | m² | ft | m |
| All | Pipe schedule | 90 | 8.4 | 12 | 3.7 |
| | | | | [In buildings with storage bays 25 ft (7.6 m) wide, 12 ft 6 in. (3.8 m) shall be permitted] | |
| All | Hydraulically calculated with density 0.25 | 100 | 9.3 | 12 | 3.7 |
| | | | | [In buildings with storage bays 25 ft (7.6 m) wide, 12 ft 6 in. (3.8 m) shall be permitted] | |
| All | Hydraulically calculated with density <0.25 | 130 | 12.1 | 15 | 4.6 |

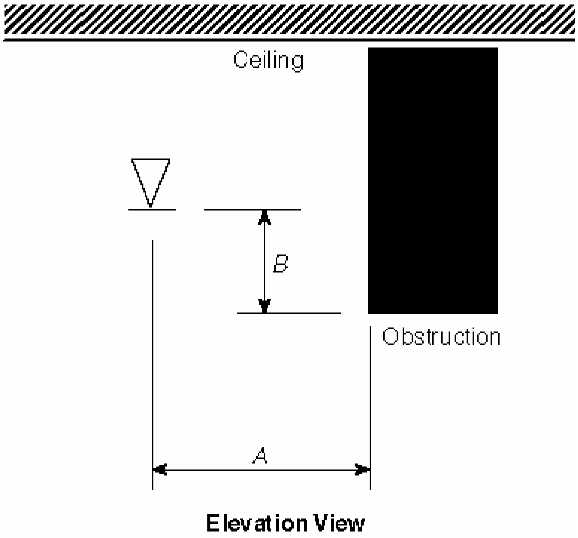
**(NFPA 13 - Table 8.6.2.2.1(c))Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for Extra Hazard**

| Construction Type | System Type | Protection Area | | Spacing (maximum) | |
|---|---|---|---|---|---|
| | | ft² | m² | ft | m |
| All | Hydraulically calculated with density 0.25 | 100 | 9.3 | 12 | 3.7 |
| | | | | [In buildings with storage bays 25 ft (7.6 m) wide, 12 ft 6 in. (3.8 m) shall be permitted] | |
| All | Hydraulically calculated with density <0.25 | 130 | 12.1 | 15 | 4.6 |

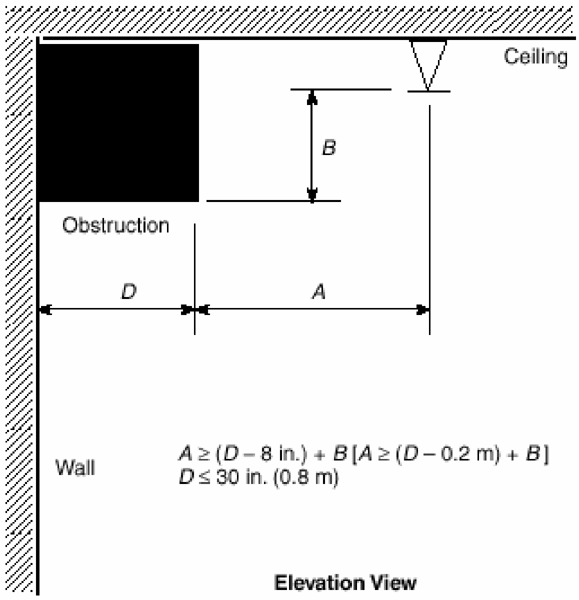
**(NFPA 13 - Table 8.6.2.2.1(d)) Protection Areas and Maximum Spacing (Standard Spray Upright/Standard Spray Pendent) for High-Piled Storage**

| Distance from Sprinklers to Side of Obstruction (A) | Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) (B) |
|---|---|
| Less than 1 ft | 0 |
| 1 ft to less than 1 ft 6 in. | 2½ |
| 1 ft 6 in. to less than 2 ft | 3½ |
| 2 ft to less than 2 ft 6 in. | 5½ |
| 2 ft 6 in. to less than 3 ft | 7½ |
| 3 ft to less than 3 ft 6 in. | 9½ |
| 3 ft 6 in. to less than 4 ft | 12 |
| 4 ft to less than 4 ft 6 in. | 14 |
| 4 ft 6 in. to less than 5 ft | 16½ |
| 5 ft and greater | 18 |
| For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m. | |
| Note: For (A) and (B), refer to Figure 8.6.5.1.2(a). | |

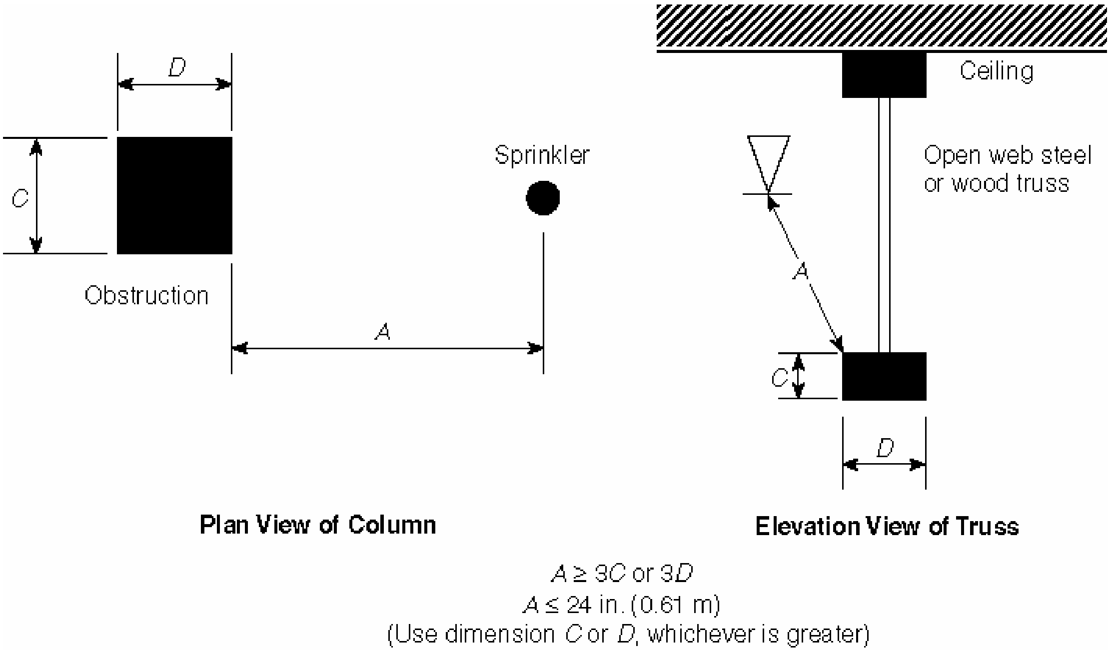
**(NFPA 13 - Table 8.6.5.1.2) Positioning of Sprinklers to Avoid Obstructions to Discharge (SSU/SSP)**




**(NFPA 13 - FIGURE 8.6.5.1.2(a)) Positioning of Sprinklers to Avoid Obstructions to Discharge (SSU/SSP).**



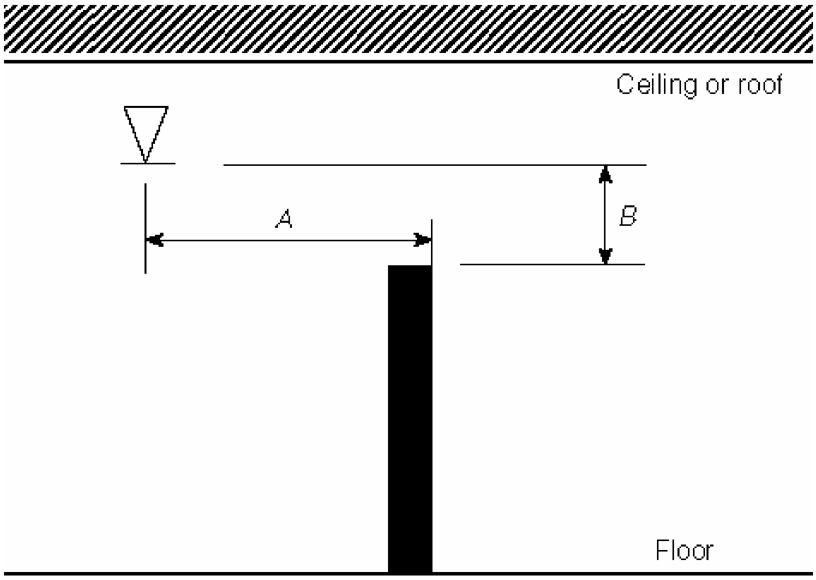

**(NFPA 13 - FIGURE 8.6.5.1.2(b)) Obstructions Against Walls (SSU/SSP).**




**(NFPA 13 - FIGURE 8.6.5.2.1.3) Minimum Distance from Obstruction (SSU/SSP).**

| Horizontal Distance (A) | Minimum Vertical Distance below Deflector (in.) (B) |
|---|---|
| 6 in. or less | 3 |
| More than 6 in. to 9 in. | 4 |
| More than 9 in. to 12 in. | 6 |
| More than 12 in. to 15 in. | 8 |
| More than 15 in. to 18 in. | 9½ |
| More than 18 in to 24 in. | 12½ |
| More than 24 in. to 30 in. | 15½ |
| More than 30 in. | 18 |
| For SI units, 1 in. = 25.4 mm. | |
| Note: For (A) and (B), refer to Figure 8.6.5.2.2. | |

**(NFPA 13 - Table 8.6.5.2.2) Suspended or Floor-Mounted Obstructions in Light Hazard Occupancies Only (SSU/SSP)**




**(NFPA 13 - FIGURE 8.6.5.2.2) Suspended or Floor-Mounted Obstructions in Light Hazard Occupancies Only (SSU/SSP).**

## 2nd) The Sidewall Standard Spray Sprinklers (NFPA 13 – 8.7):-

### General Sprinklers Spacing Notes:-

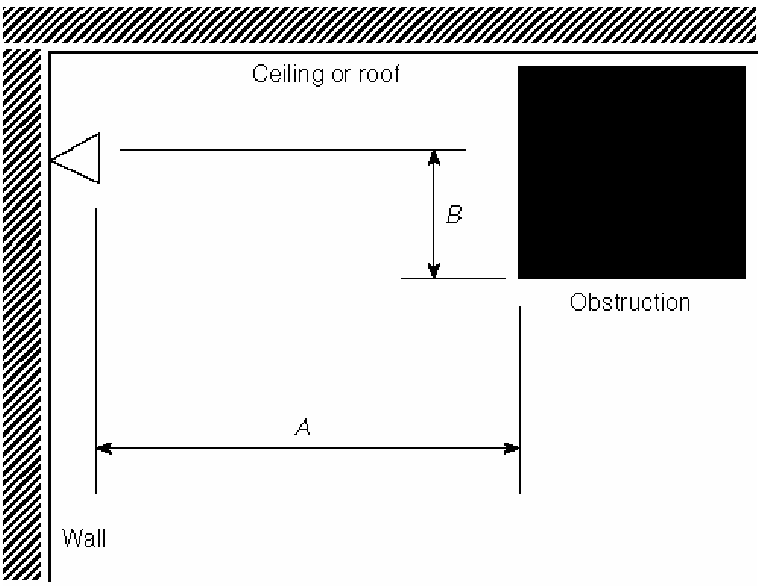
- In any case, the maximum area of coverage of a sprinkler shall not exceed 196 $ft^2$ (18.2 $m^2$).
- Sprinklers shall be located a minimum of 4 in. (102 mm) from an end wall.
- The distance from the wall to the sprinkler shall be measured perpendicular to the wall.
- Sprinklers shall be spaced not less than 6 ft (1.8 m) on center.

| | Light Hazard | | Ordinary Hazard | |
|---|---|---|---|---|
| | **Combustible Finish** | **Noncombustible or Limited Combustible Finish** | **Combustible Finish** | **Noncombustible or Limited Combustible Finish** |
| Maximum distance along the wall (S) | 14 ft | 14 ft | 10 ft | 10 ft |
| Maximum room width (L) | 12 ft | 14 ft | 10 ft | 10 ft |
| Maximum protection area | 120 $ft^2$ | 196 $ft^2$ | 80 $ft^2$ | 100 $ft^2$ |
| For SI units, 1 ft = 0.3048 m; 1 ft2 = 0.0929 m2. | | | | |

**(NFPA 13 - Table 8.7.2.2.1) Protection Areas and Maximum Spacing (Standard Sidewall Spray Sprinkler)**

| Distance from Sidewall Sprinkler to Side of Obstruction (A) | Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) (B) |
|---|---|
| Less than 4 ft | Not allowed |
| 4 ft to less than 5 ft | 1 |
| 5 ft to less than 5 ft 6 in. | 2 |
| 5 ft 6 in. to less than 6 ft | 3 |
| 6 ft to less than 6 ft 6 in. | 4 |
| 6 ft 6 in. to less than 7 ft | 6 |
| 7 ft to less than 7 ft 6 in. | 7 |
| 7 ft 6 in. to less than 8 ft | 9 |
| 8 ft to less than 8 ft 6 in. | 11 |
| 8 ft 6 in. or greater | 14 |
| For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m. | |
| Note: For (A) and (B), refer to Figure 8.7.5.1.3. | |

**(NFPA 13 - Table 8.7.5.1.3) Positioning of Sprinklers to Avoid Obstructions (Standard Sidewall Spray Sprinklers)**

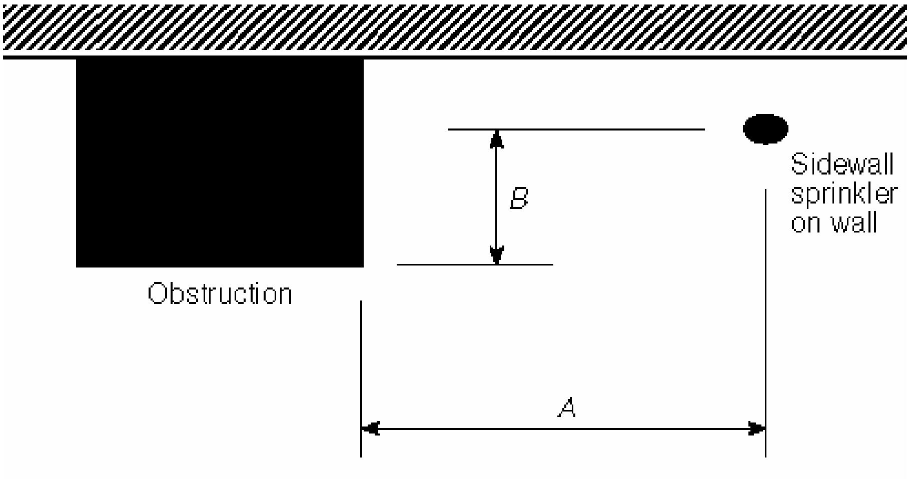



Elevation View

**(NFPA 13 - FIGURE 8.7.5.1.3) Positioning of Sprinklers to Avoid Obstructions (Standard Sidewall Spray Sprinklers).**

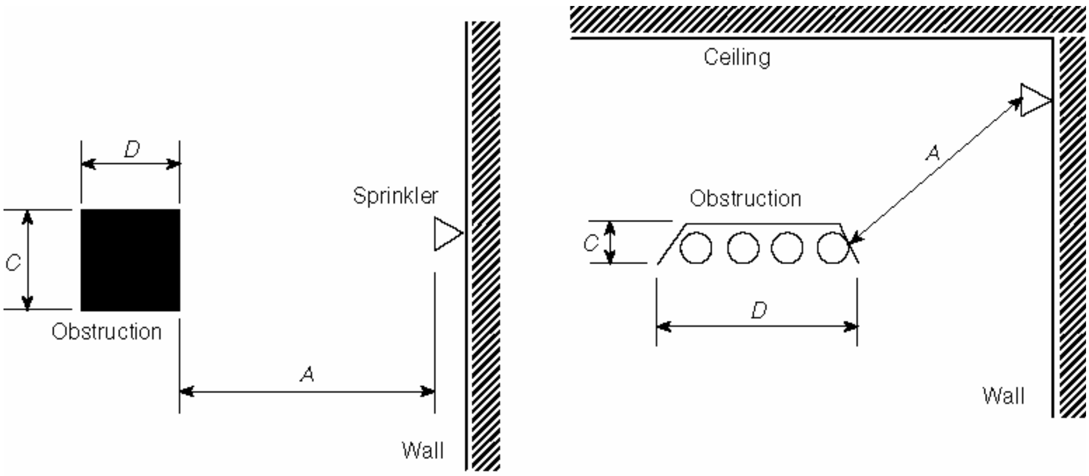
| Distance from Sidewall Sprinkler to Side of Obstruction (A) | Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) (B) |
|---|---|
| Less than 6 in. | 1 |
| 6 in. to less than 1 ft | 2 |
| 1 ft to less than 1 ft 6 in. | 3 |
| 1 ft 6 in. to less than 2 ft | 4½ |
| 2 ft to less than 2 ft 6 in. | 5¾ |
| 2 ft 6 in. to less than 3 ft | 7 |
| 3 ft to less than 3 ft 6 in. | 8 |
| 3 ft 6 in. to less than 4 ft | 9¼ |
| 4 ft to less than 4 ft 6 in. | 10 |
| 4 ft 6 in. to less than 5 ft | 11½ |
| 5 ft to less than 5 ft 6 in. | 12¾ |
| 5 ft 6 in. to less than 6 ft | 14 |
| 6 ft to less than 6 ft 6 in. | 15 |
| 6 ft 6 in. to less than 7 ft | 16¼ |
| 7 ft to less than 7 ft 6 in. | 17½ |
| For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m. | |
| Note: For (A) and (B), refer to Figure 8.7.5.1.4. | |

**(NFPA 13 - Table 8.7.5.1.4) Positioning of Sprinklers to Avoid Obstructions Along the Wall (Standard Sidewall Spray Sprinklers)**




**Elevation View**

**(NFPA 13 - FIGURE 8.7.5.1.4) Positioning of Sprinklers to Avoid Obstructions Along the Wall (Standard Sidewall Spray Sprinklers)**



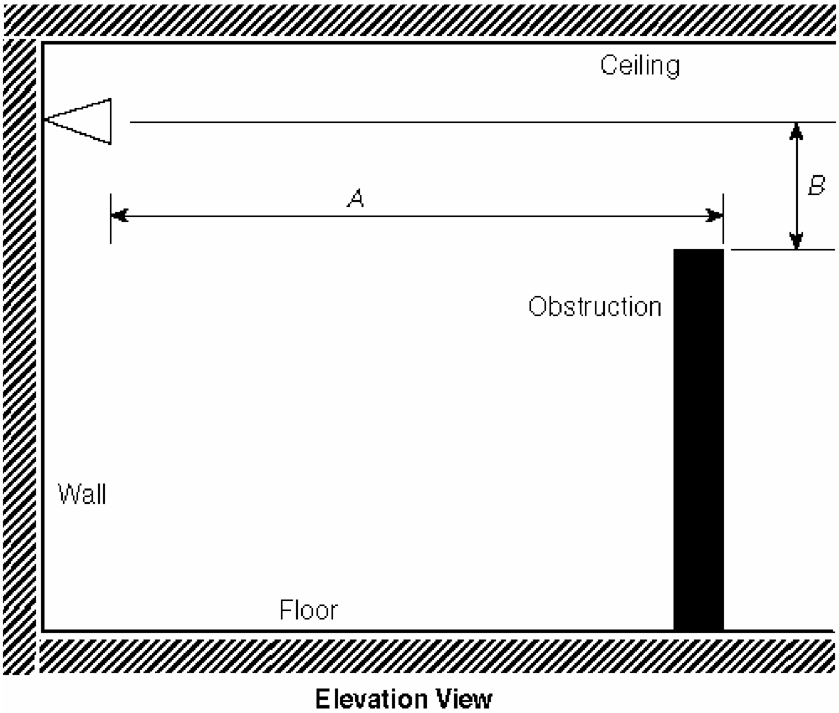

**Plan View of Column** | **Elevation View of Pipe Conduit or Light Fixture**

$A \geq 3C$ or $3D$
$A \leq 24$ in. (0.61 m)
(Use dimension $C$ or $D$, whichever is greater)

**(NFPA 13 - FIGURE 8.7.5.2.1.3) Minimum Distance from Obstruction (Standard Sidewall Spray Sprinkler)**

| Horizontal Distance (A) | Minimum Vertical Distance below Deflector (in.) (B) |
|---|---|
| 6 in. or less | 3 |
| More than 6 in. to 9 in. | 4 |
| More than 9 in. to 12 in. | 6 |
| More than 12 in. to 15 in. | 8 |
| More than 15 in. to 18 in. | 9½ |
| More than 18 in. to 24 in. | 12½ |
| More than 24 in. to 30 in. | 15½ |
| More than 30 in. | 18 |
| For SI units, 1 in. = 25.4 mm. | |
| Note: For (A) and (B), refer to Figure 8.7.5.2.2. | |

**(NFPA 13 - Table 8.7.5.2.2) Suspended or Floor-Mounted Obstructions (Standard Sidewall Spray Sprinklers)**




**(NFPA 13 - FIGURE 8.7.5.2.2) Suspended or Floor-Mounted Obstructions (Standard Sidewall Spray Sprinklers).**

## 2-)Early Suppression Fast-Response (ESFR) Sprinkler.(K=11.2 or more)

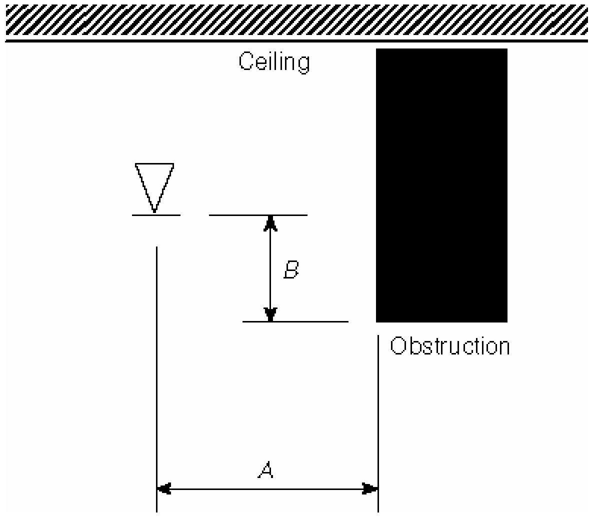
- Fast-response sprinkler RTI <= 50 $(m.s)^{1/2}$
- Intermediate or High temperature rating.
- **High-challenge** fire hazards.(Used in storage NFPA 13–Ch12)
- Used only in wet pipe systems unless specifically listed for use in dry systems.
- Used in buildings where roof or ceiling slope above the sprinklers does not exceed a pitch of two in 12 (a roof slope of 16.7 percent).

| Construction Type | Ceiling/Roof Heights up to 30 ft (9.1 m) | | | | Ceiling/Roof Heights over 30 ft (9.1 m) | | | |
|---|---|---|---|---|---|---|---|---|
| | Protection Area | | Spacing | | Protection Area | | Spacing | |
| | $ft^2$ | $m^2$ | ft | m | $ft^2$ | $m^2$ | ft | m |
| Noncombustible unobstructed | 100 | 9.3 | 12 | 3.7 | 100 | 9.3 | 10 | 3.1 |
| Noncombustible obstructed | 100 | 9.3 | 12 | 3.7 | 100 | 9.3 | 10 | 3.1 |
| Combustible unobstructed | 100 | 9.3 | 12 | 3.7 | 100 | 9.3 | 10 | 3.1 |
| Combustible obstructed | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

**(NFPA 13 - Table 8.12.2.2.1) Protection Areas and Maximum Spacing of ESFR Sprinklers**

| Distance from Sprinkler to Side of Obstruction (A) | Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) (B) |
|---|---|
| Less than 1 ft | 0 |
| 1 ft to less than 1 ft 6 in. | 1½ |
| 1 ft 6 in. to less than 2 ft | 3 |
| 2 ft to less than 2 ft 6 in. | 5½ |
| 2 ft 6 in. to less than 3 ft | 8 |
| 3 ft to less than 3 ft 6 in. | 10 |
| 3 ft 6 in. to less than 4 ft | 12 |
| 4 ft to less than 4 ft 6 in. | 15 |
| 4 ft 6 in. to less than 5 ft | 18 |
| 5 ft to less than 5 ft 6 in. | 22 |
| 5 ft 6 in. to less than 6 ft | 26 |
| 6 ft | 31 |
| For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.<br>Note: For (A) and (B), refer to Figure 8.12.5.1.1. | |

**(NFPA 13 - Table 8.12.5.1.1) Positioning of Sprinklers to Avoid Obstructions to Discharge (ESFR Sprinkler)**




**(NFPA 13 - FIGURE 8.12.5.1.1) Positioning of Sprinklers to Avoid Obstructions to Discharge (ESFR Sprinkler).**

3-) Extended Coverage Sprinkler. A type of spray sprinkler with large coverage areas.

- Used in Unobstructed construction consisting of flat, smooth ceilings with a slope not exceeding a pitch of one in six (a roof slope of 16.7 percent)
- Or Unobstructed or noncombustible obstructed construction.Within trusses not greater than 1 in. (25.4 mm) maximum dimension or where trusses arespaced greater than 7½ ft (2.3 m) on center and where the ceiling slope does not exceed a pitch of one in six (a roof slope of 16.7 percent).
- Or Under smooth, flat ceilings that have slopes not exceeding a pitch of one in three (a roof slope of 33.3 percent).
- Clearance between the deflector and the top of storage shall be 18 in or greater.
- Minimum design area shall be that corresponding to the maximum density for the hazard in Figure 11.2.3.1.5 or the area protected by **five sprinklers**, whichever is **greater**.

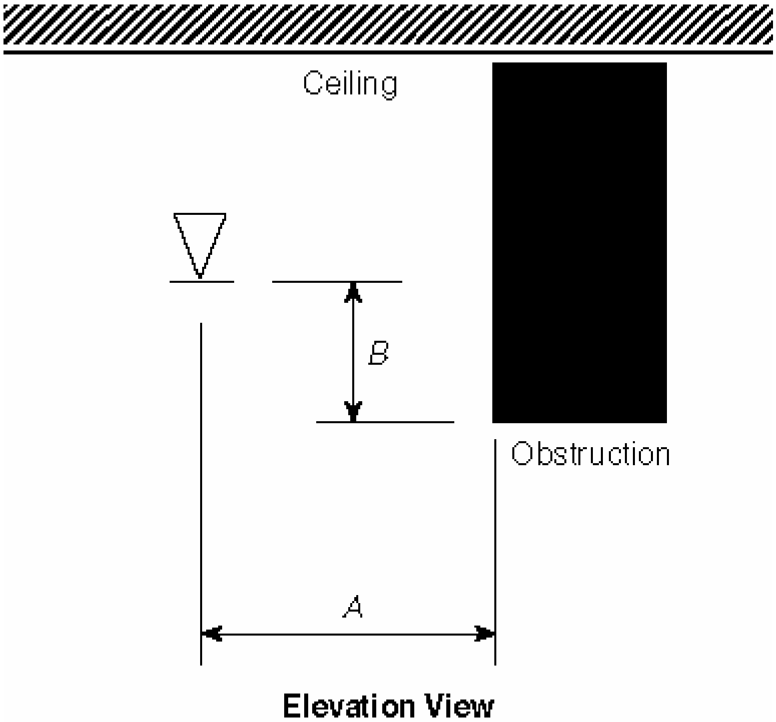
1st) The upright or pendent extended coverage sprinkler

| Construction Type | Light Hazard | | Ordinary Hazard | | Extra Hazard | | High-Piled Storage | |
|---|---|---|---|---|---|---|---|---|
| | Protection Area ($ft^2$) | Spacing (ft) | Protection Area ($ft^2$) | Spacing (ft) | Protection Area ($ft^2$) | Spacing (ft) | Protection Area ($ft^2$) | Spacing (ft) |
| Unobstructed | 400 | 20 | 400 | 20 | — | — | — | — |
| | 324 | 18 | 324 | 18 | — | — | — | — |
| | 256 | 16 | 256 | 16 | — | — | — | — |
| | — | — | 196 | 14 | 196 | 14 | 196 | 14 |
| | — | — | 144 | 12 | 144 | 12 | 144 | 12 |
| | 400 | 20 | 400 | 20 | — | — | — | — |
| | 324 | 18 | 324 | 18 | — | — | — | — |
| | 256 | 16 | 256 | 16 | — | — | — | — |
| Obstructed noncombustible (when specifically listed for such use) | — | — | 196 | 14 | 196 | 14 | 196 | 14 |
| | — | — | 144 | 12 | 144 | 12 | 144 | 12 |
| Obstructed combustible | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| For SI units, 1 ft = 0.3048 m; 1 ft2 = 0.0929 m2. | | | | | | | | |

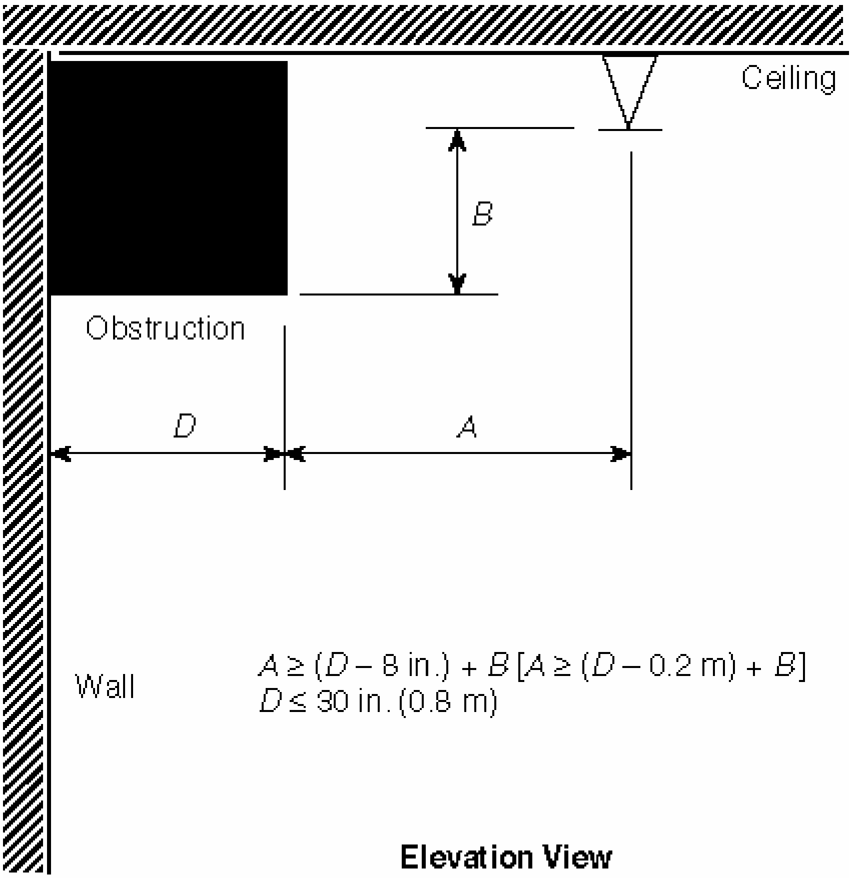
**(NFPA 13 - Table 8.8.2.1.2) Protection Areas and Maximum Spacing (Extended Coverage Upright and Pendent Spray Sprinklers)**

| Distance from Sprinklers to Side of Obstruction (A) | Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) (B) |
|---|---|
| Less than 1 ft | 0 |
| 1 ft to less than 1 ft 6 in. | 0 |
| 1 ft 6 in. to less than 2 ft | 1 |
| 2 ft to less than 2 ft 6 in. | 1 |
| 2 ft 6 in. to less than 3 ft | 1 |
| 3 ft to less than 3 ft 6 in. | 3 |
| 3 ft 6 in. to less than 4 ft | 3 |
| 4 ft to less than 4 ft 6 in. | 5 |
| 4 ft 6 in. to less than 5 ft | 7 |
| 5 ft to less than 5 ft 6 in. | 7 |
| 5 ft 6 in. to less than 6 ft | 7 |
| 6 ft to less than 6 ft 6 in. | 9 |
| 6 ft 6 in. to less than 7 ft | 11 |
| 7 ft and greater | 14 |
| For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m. | |
| Note: For (A) and (B), refer to Figure 8.8.5.1.2(a). | |

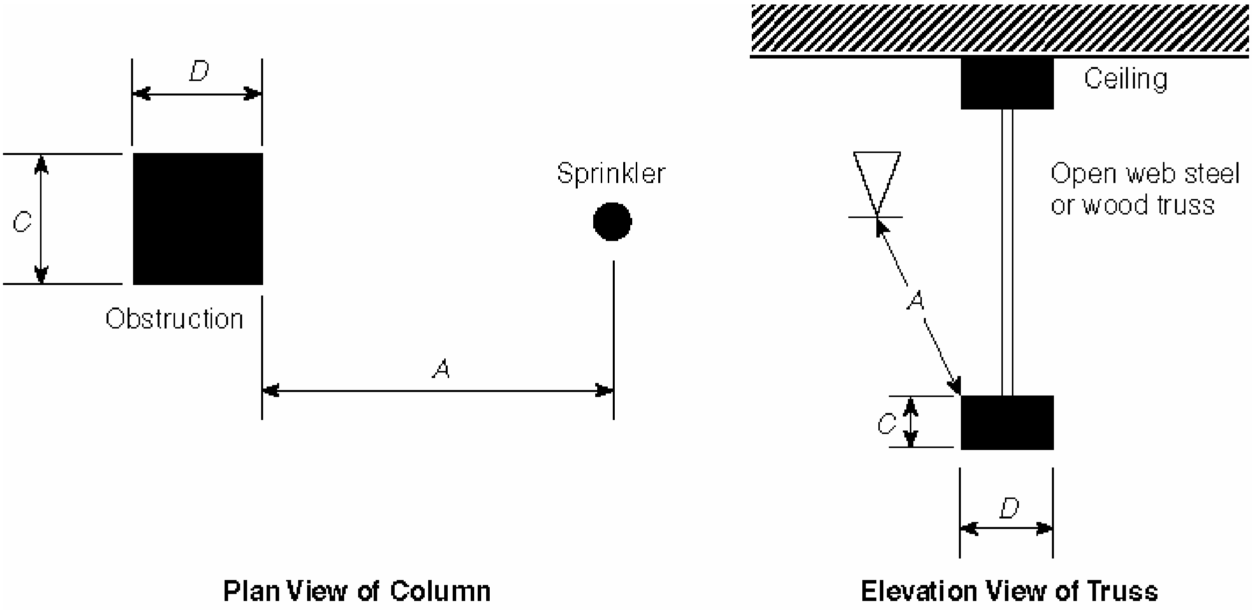
**(NFPA 13 - Table 8.8.5.1.2) Position of Sprinklers to Avoid Obstructions to Discharge (Extended Coverage Upright and Pendent Spray Sprinklers)**




**(NFPA 13 - FIGURE 8.8.5.1.2(a)) Position of Sprinklers to Avoid Obstructions to Discharge (Extended Coverage Upright and Pendent Spray Sprinklers).**




**(NFPA 13 - FIGURE 8.8.5.1.2(b)) Obstructions Against Walls (Extended Coverage Upright and Pendent Spray Sprinklers).**




$A \geq 4C$ or $4D$

$A \leq 36$ in. (0.91 m)

(Use dimension $C$ or $D$, whichever is greater)

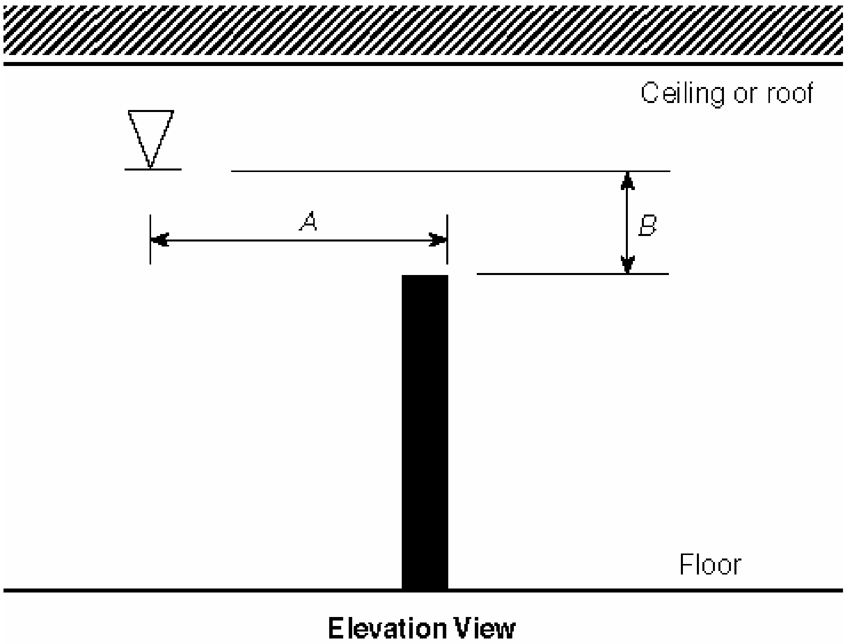
**(NFPA 13 - FIGURE 8.8.5.2.1.3) Minimum Distance from Obstruction (Extended Coverage Upright and Pendent Spray Sprinklers).**

| Horizontal Distance (A) | Minimum Vertical Distance below Deflector (in.) (B) |
|---|---|
| 6 in. or less | 3 |
| More than 6 in. to 9 in. | 4 |
| More than 9 in. to 12 in. | 6 |
| More than 12 in. to 15 in. | 8 |
| More than 15 in. to 18 in. | 9½ |
| More than 18 in. to 24 in. | 12½ |
| More than 24 in. to 30 in. | 15½ |
| More than 30 in. | 18 |

For SI units, 1 in. = 25.4 mm.

Note: For (A) and (B), refer to Figure 8.8.5.2.2.

**(NFPA 13- Table 8.8.5.2.2) Suspended or Floor-Mounted Obstructions (Extended Coverage Upright and Pendent Spray Sprinklers)**




**(NFPA 13 - FIGURE 8.8.5.2.2) Suspended or Floor-Mounted Obstructions (Extended Coverage Upright and Pendent Spray Sprinklers).**

2nd) The Sidewall extended coverage sprinkler

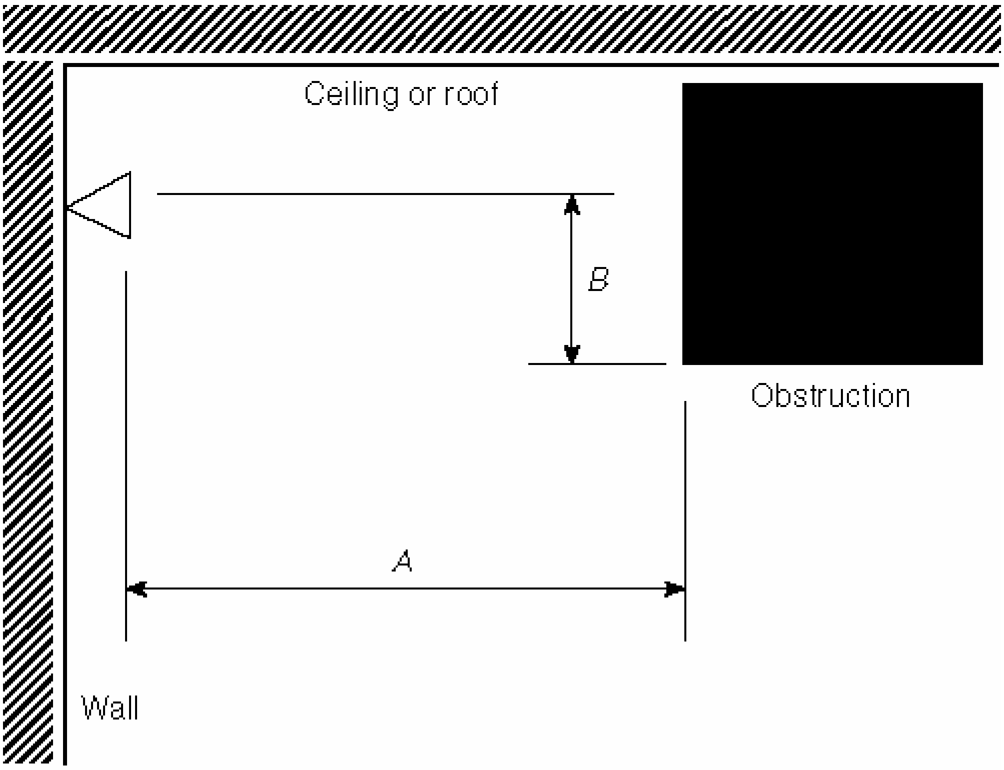
| Construction Type | Light Hazard | | | | Ordinary Hazard | | | |
|---|---|---|---|---|---|---|---|---|
| | Protection Area | | Spacing | | Protection Area | | Spacing | |
| | $ft^2$ | $m^2$ | ft | m | $ft^2$ | $m^2$ | ft | m |
| Unobstructed, smooth, flat | 400 | 37.2 | 28 | 8.5 | 400 | 37.2 | 24 | 7.3 |

**(NFPA 13 - Table 8.9.2.2.1) Protection Area and Maximum Spacing for Extended Coverage Sidewall Sprinklers**

| Distance from Sidewall Sprinkler to Side of Obstruction (A) | Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) (B) |
|---|---|
| Less than 8 ft | Not allowed |
| 8 ft to less than 10 ft | 1 |
| 10 ft to less than 11 ft | 2 |
| 11 ft to less than 12 ft | 3 |
| 12 ft to less than 13 ft | 4 |
| 13 ft to less than 14 ft | 6 |
| 14 ft to less than 15 ft | 7 |
| 15 ft to less than 16 ft | 9 |
| 16 ft to less than 17 ft | 11 |
| 17 ft or greater | 14 |

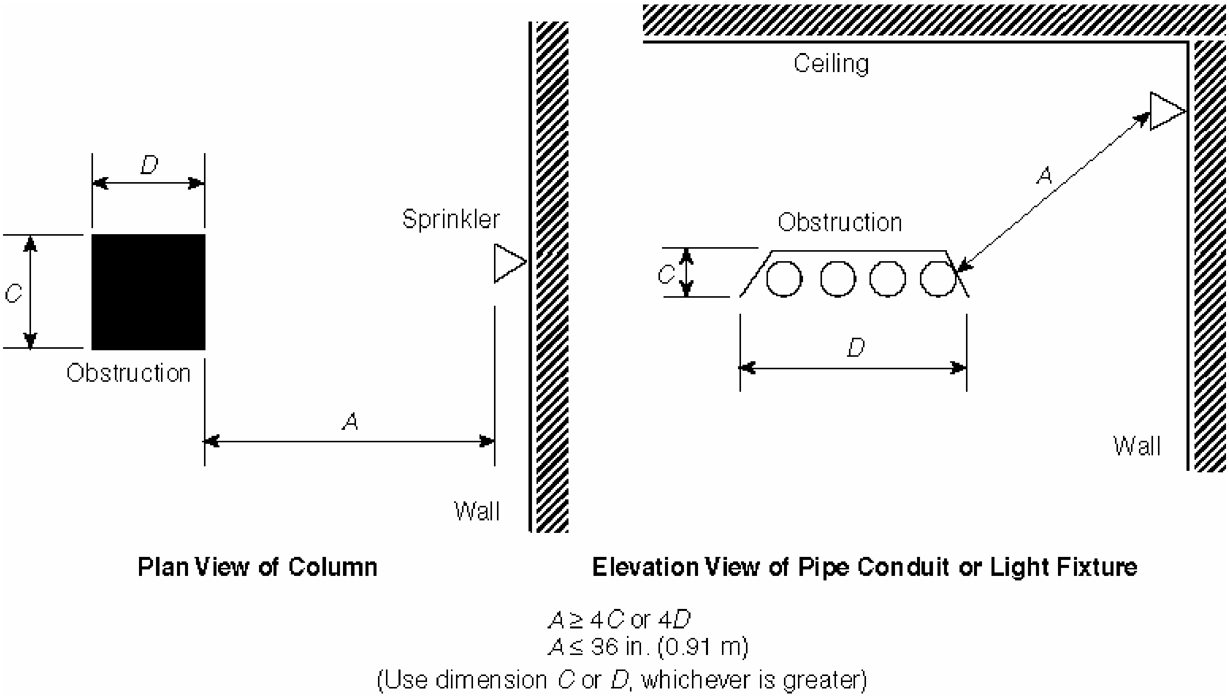
For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: For (A) and (B), refer to Figure 8.9.5.1.3.

**(NFPA 13 - Table 8.9.5.1.3) Positioning of Sprinklers to Avoid Obstructions (Extended Coverage Sidewall Sprinklers)**




**Elevation View**

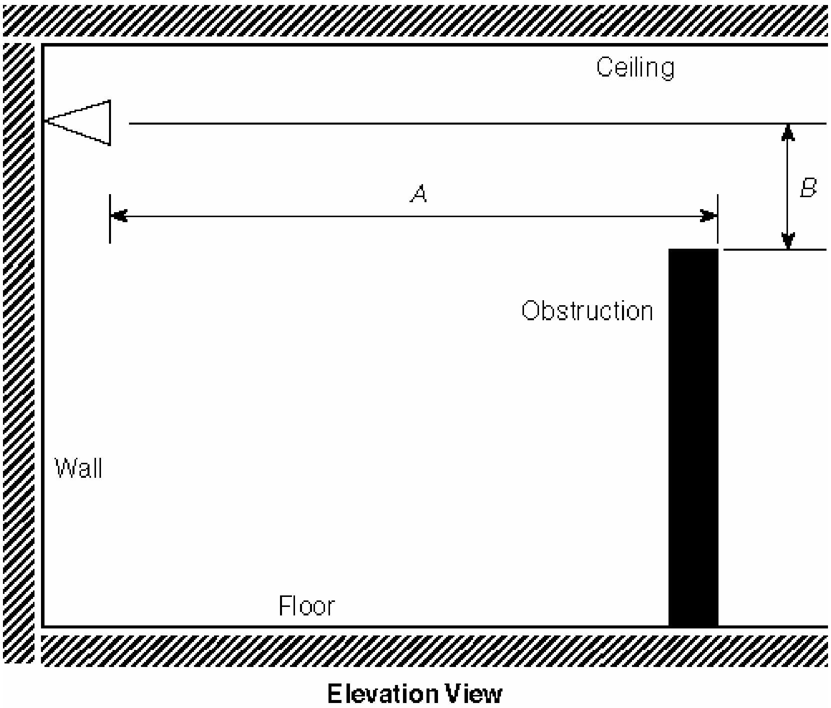
**(NFPA 13 - FIGURE 8.9.5.1.3) Positioning of Sprinklers to Avoid Obstructions (Extended Coverage Sidewall Sprinklers).**




**(NFPA 13 - FIGURE 8.9.5.2.1.4) Minimum Distance from Obstruction (Extended Coverage Sidewall).**

| Horizontal Distance (A) | Minimum Vertical Distance below Deflector (in.) (B) |
|---|---|
| 6 in. or less | 3 |
| More than 6 in. to 9 in. | 4 |
| More than 9 in. to 12 in. | 6 |
| More than 12 in. to 15 in. | 8 |
| More than 15 in. to 18 in. | 9½ |
| More than 18 in. to 24 in. | 12½ |
| More than 24 in. to 30 in. | 15½ |
| More than 30 in. | 18 |
| For SI units, 1 in. = 25.4 mm. | |
| Note: For (A) and (B), refer to Figure 8.9.5.2.2. | |

**(NFPA 13 - Table 8.9.5.2.2) Suspended or Floor-Mounted Obstructions (Extended Coverage Sidewall Sprinklers)**




**(NFPA 13 - FIGURE 8.9.5.2.2) Suspended or Floor-Mounted Obstructions (Extended Coverage Sidewall Sprinklers).**

## 4-) Large Drop Sprinkler.(K=11.2 or more).

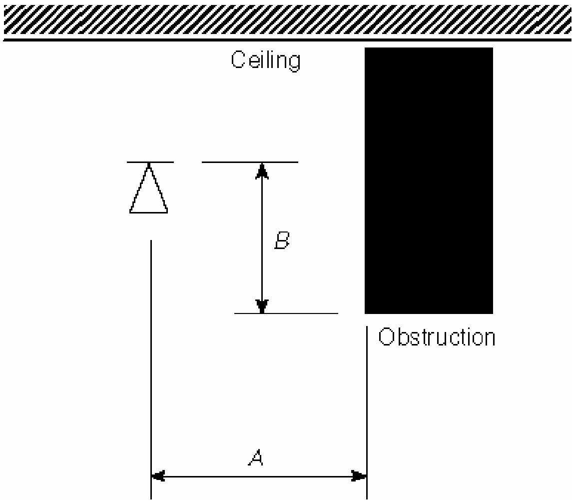
- Used in wet, dry or preaction systems.
- Capable of producing characteristic large water droplets and that is listed for its capability to provide fire control of specific **high-challenge** fire hazards.
- Sprinklers shall be permitted to be attached directly to branch lines less than 2 in. (51 mm) in diameter.
- Sprinklers shall be permitted to be offset horizontally a minimum of 12 in. (305 mm) from the pipe.
- Sprinklers shall be permitted to be supplied by a riser nipple to elevate the sprinkler deflector a minimum of 13 in. (330 mm) from the centerline of 2½-in. (64-mm) pipe.
- Sprinklers shall be permitted to be supplied by a riser nipple to elevate the sprinkler deflector a minimum of 15 in. (380 mm) from the centerline of 3-in. (76-mm) pipe.

| Construction Type | Protection Area | | Maximum Spacing | |
|---|---|---|---|---|
| | $ft^2$ | $m^2$ | ft | m |
| Noncombustible unobstructed | 130 | 12.1 | 12 | 3.7 |
| Noncombustible obstructed | 130 | 12.1 | 12 | 3.7 |
| Combustible unobstructed | 130 | 12.1 | 12 | 3.7 |
| Combustible obstructed | 100 | 9.3 | 10 | 3.1 |
| Rack storage applications | 100 | 9.3 | 10 | 3.1 |

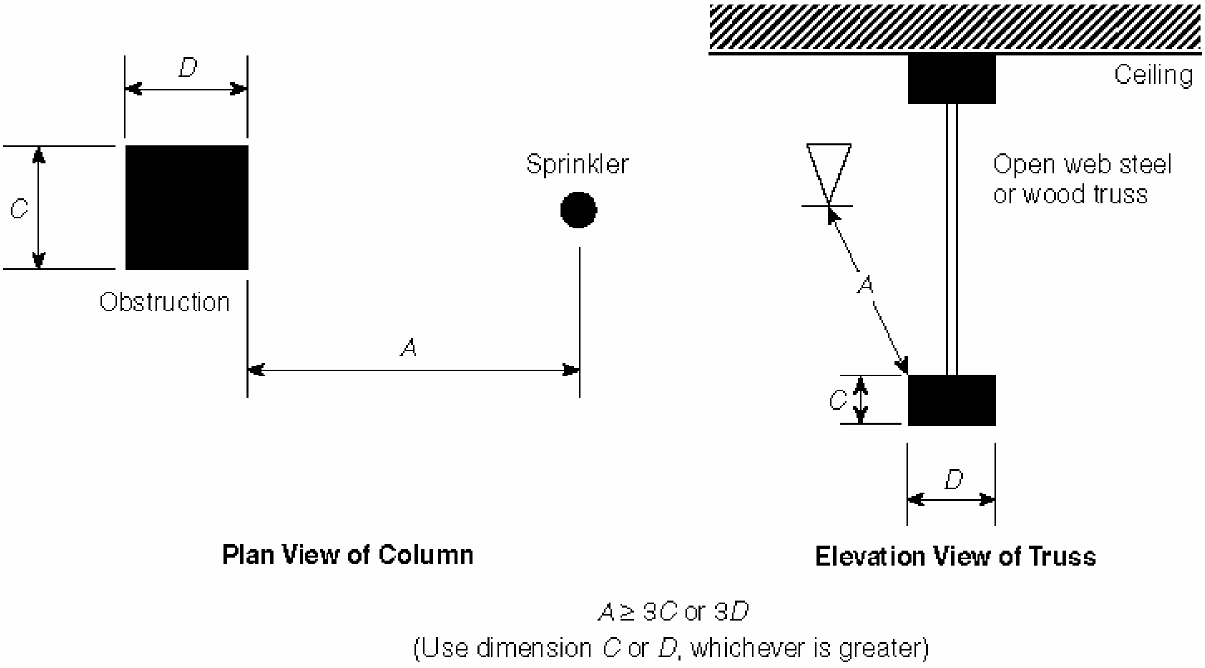
**(NFPA 13 - Table 8.11.2.2.1) Protection Areas and Maximum Spacing for Large Drop Sprinklers**

| Distance from Sprinkler to Side of Obstruction (A) | Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.) (B) |
|---|---|
| Less than 1 ft. | 0 |
| 1 ft to less than 1 ft 6 in. | 1½ |
| 1 ft 6 in. to less than 2 ft | 3 |
| 2 ft to less than 2 ft 6 in. | 5½ |
| 2 ft 6 in. to less than 3 ft | 8 |
| 3 ft to less than 3 ft 6 in. | 10 |
| 3 ft 6 in. to less than 4 ft | 12 |
| 4 ft to less than 4 ft 6 in. | 15 |
| 4 ft 6 in. to less than 5 ft | 18 |
| 5 ft to less than 5 ft 6 in. | 22 |
| 5 ft 6 in. to less than 6 ft | 26 |
| 6 ft | 31 |
| For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m. | |
| Note: For (A) and (B), refer to Figure 8.11.5.1.2. | |

**(NFPA 13 - Table 8.11.5.1.2) Positioning of Sprinklers to Avoid Obstructions to Discharge (Large Drop Sprinkler)**



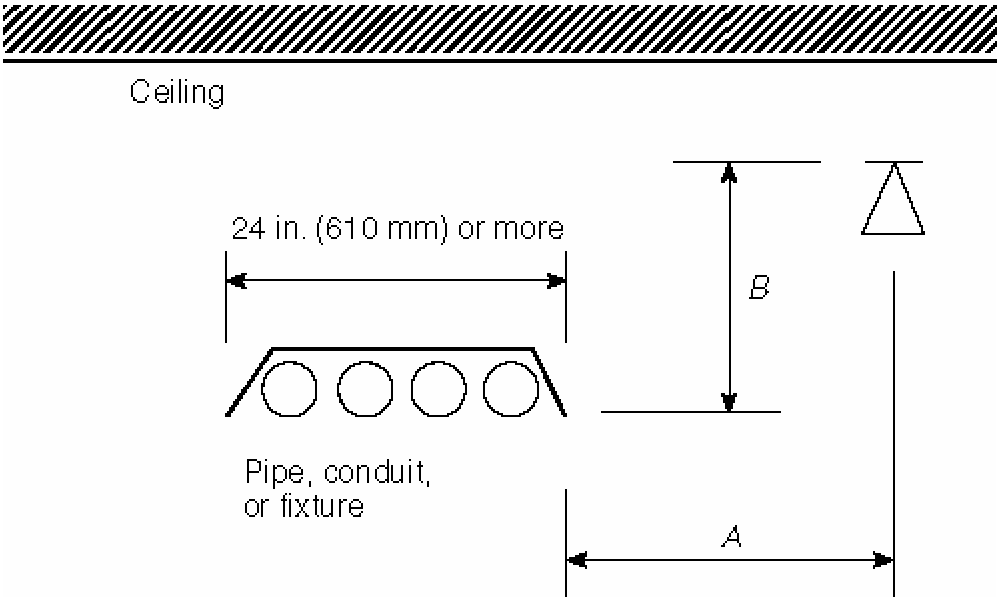

**(NFPA 13 - FIGURE 8.11.5.1.2) Positioning of Sprinklers to Avoid Obstructions to Discharge (Large Drop Sprinkler).**



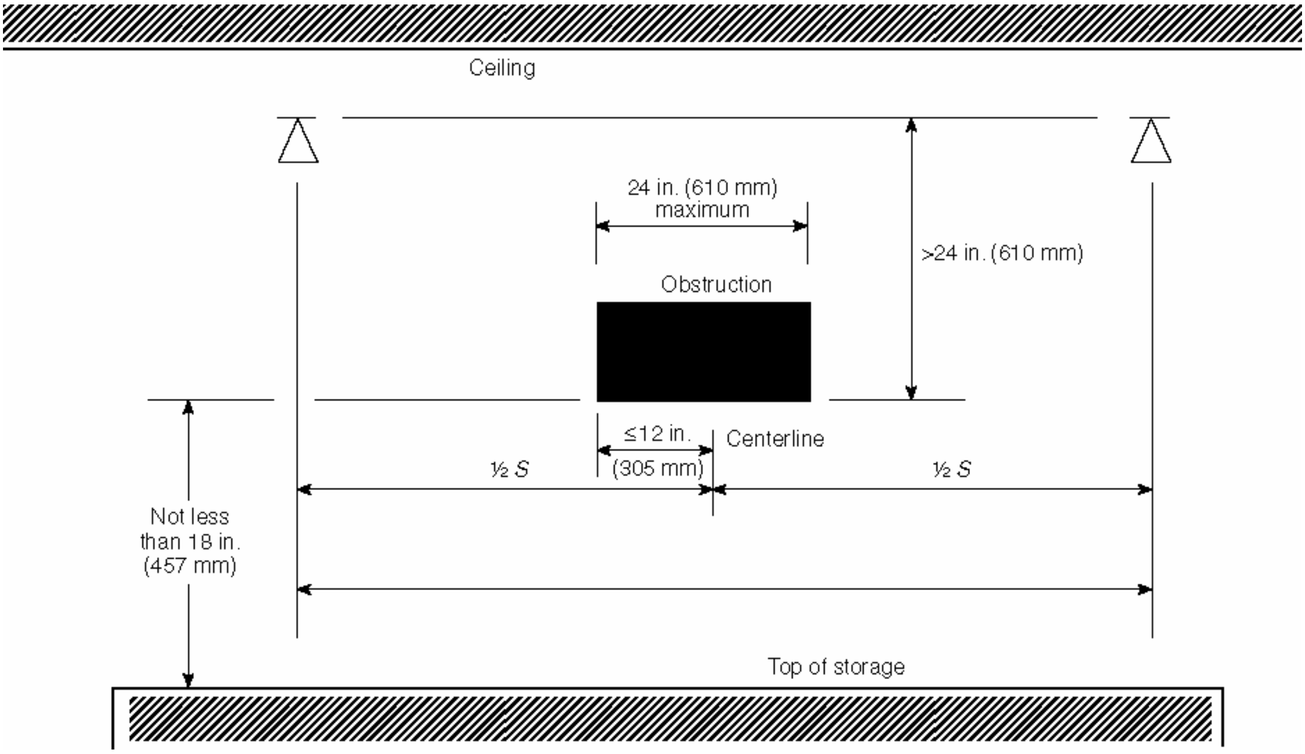

**(NFPA 13 - FIGURE 8.11.5.2.1.3) Minimum Distance from Obstruction (Large Drop Sprinkler).**

| Distance of Deflector above Bottom of Obstruction (B) | Minimum Distance to Side of Obstruction (ft) (A) |
|---|---|
| Less than 6 in. | 1½ |
| 6 in. to less than 12 in. | 3 |
| 12 in. to less than 18 in. | 4 |
| 18 in. to less than 24 in. | 5 |
| 24 in. to less than 30 in | 5½ |
| 30 in. less than 36 in. | 6 |
| For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m. | |
| Note: For (A) and (B), refer to Figure 8.11.5.3.2. | |

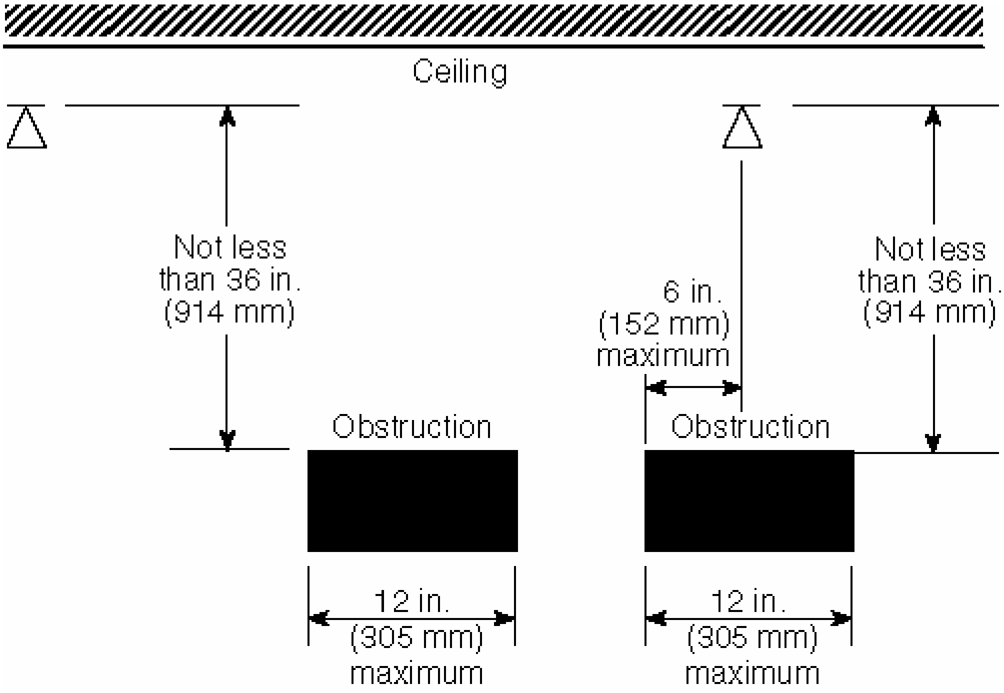
**(NFPA 13 - Table 8.11.5.3.2) Obstruction Entirely Below the Sprinkler (Large Drop Sprinkler)**




**(NFPA 13 - FIGURE 8.11.5.3.2) Obstruction Entirely Below the Sprinkler (Large Drop Sprinkler).**




**(NFPA 13- FIGURE 8.11.5.3.4) Obstruction More Than 24 in. (610 mm) Below the Sprinkler (Large Drop Sprinkler).**




**(NFPA 13 - FIGURE 8.11.5.3.5) Obstruction More Than 36 in. (914 mm) Below the Sprinkler (Large Drop Sprinkler).**

5-) Nozzles. A device for use in applications requiring special water discharge patterns, directional spray, or other unusual discharge characteristics.

6-) Old-Style/Conventional Sprinkler.

- A sprinkler that directs from 40 percent to 60 percent of the total water initially in a downward direction and that is designed to be installed with the deflector either upright or pendent.
- Old-style sprinklers protecting fur storage vaults shall be permitted to be placed less than 6 ft (1.8 m) on center.

7-) Open Sprinkler.

- A sprinkler that does not have actuators or heat-responsive elements.
- Used with Deluge systems.

8-) Quick-Response (QR) Sprinkler. A type of spray sprinkler that have a thermal element with an RTI of 50 (meters-seconds)1/2 or less.

9-) Quick-Response Early Suppression (QRES) Sprinkler. A type of quick-response sprinkler that have the same characteristics of Early Suppression sprinkler but with quick response.

10-) Quick-Response Extended Coverage Sprinkler. A type of quick-response sprinkler that have the same characteristics of extended coverage sprinkler but with quick response.

11-) Residential Sprinkler. A type of fast-response sprinkler that have a thermal element with an RTI of 50 (meters-seconds)1/2 or less and has been specifically investigated for its ability to enhance survivability in the room of fire origin and is listed for use in the protection of dwelling units.

12-) Special Sprinkler.
Special sprinklers that are intended for the protection of specific hazards or construction features shall be permitted where such devices have been evaluated and listed for performance under the following conditions:-

(1) Fire tests related to the intended hazard
(2) Distribution of the spray pattern with respect to wetting of floors and walls
(3) Distribution of the spray pattern with respect to obstructions
(4) Evaluation of the thermal sensitivity of the sprinkler
(5) Performance under horizontal or sloped ceilings
(6) Area of design

Special sprinklers shall maintain the following characteristics:-

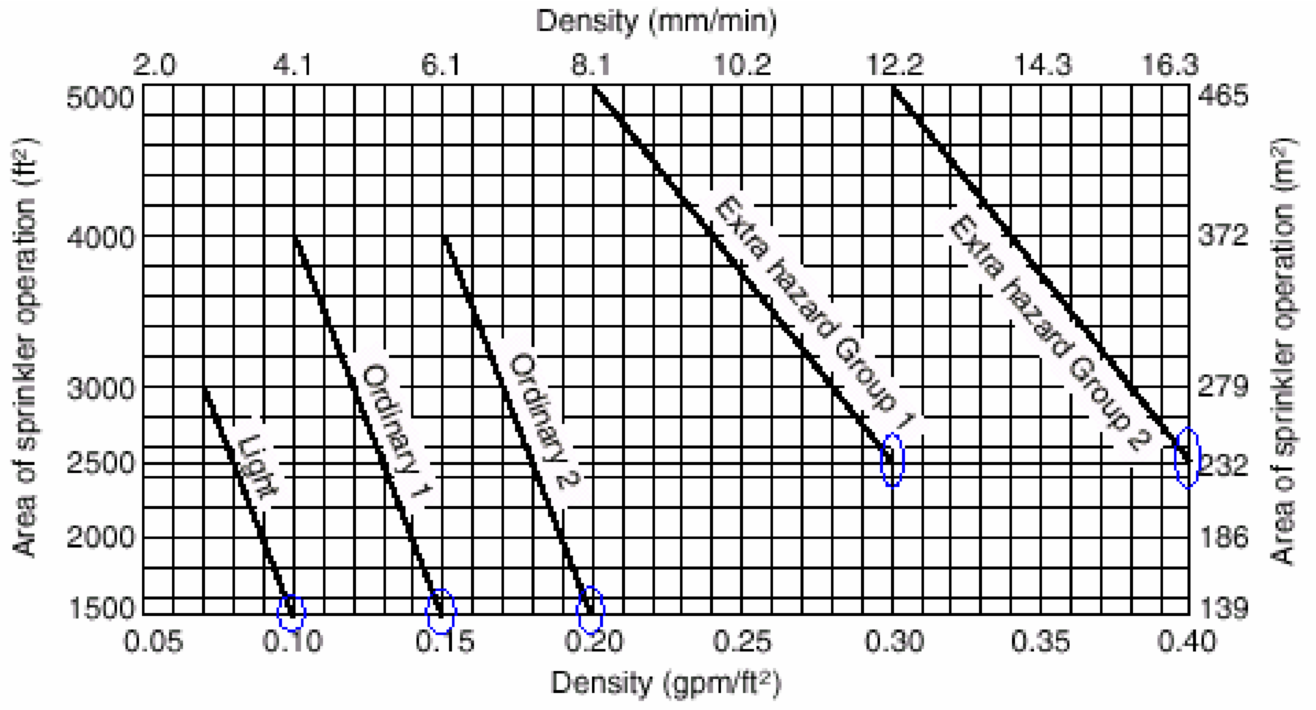
(1) Orifice size shall be in accordance with 6.2.3.
(2) Temperature ratings shall be in accordance with Table 6.2.5.1.
(3) The protection area of coverage shall not exceed 400 ft2 (36 m2) for light hazard and ordinary hazard occupancies.
(4) The protection area of coverage shall not exceed 196 ft2 (17 m2) for extra hazard and high-piled storage occupancies.

13-) Specific Application Control Mode Sprinkler (for Storage Use). A type of spray sprinkler listed at a minimum operating pressure with a specific number of operating sprinklers for a given protection scheme.

14-) Spray Sprinkler. A type of sprinkler listed for its capability to provide fire control for a wide range of fire hazards.

## 4- Sprinklers Operation Area (NFPA 13 - 11.2.3.1.5)

Density/Area Curves. The water supply for sprinklers only shall be Calculated by selecting a point on the Hazard curve of the system then Determine the area of Sprinklers Operation and the density.




**(NFPA 13 - FIGURE 11.2.3.1.5) Density/Area Curves.**

Usually we select the point at the bottom of each curve as marked on chart and this leads us to the following table:-

| No. | Hazard | Area of Sprinklers Operation | | Density | |
|---|---|---|---|---|---|
| | | $m^2$ | $ft^2$ | mm/min | $gpm/ft^2$ |
| a | Light Hazard | 139 | 1500 | 4.1 | 0.1 |
| b.1 | Ordinary Hazard (Group 1) | 139 | 1500 | 6.1 | 0.15 |
| b.2 | Ordinary Hazard (Group 2) | 139 | 1500 | 8.1 | 0.2 |
| c.1 | Extra Hazard (Group 1) | 232 | 2500 | 12.2 | 0.3 |
| c.2 | Extra Hazard (Group 2) | 232 | 2500 | 16.3 | 0.4 |

Apply the sprinklers operation area on the most remote area in the system.

## 5- Hose Discharge Requirements (NFPA 13 - 11.2.3.1.1)

| Occupancy Classification | Inside Hose (gpm) | Total Combined Inside and Outside Hose (gpm) | Duration (minutes) |
|---|---|---|---|
| Light hazard | 0, 50, or 100 | 100 | 30 |
| Ordinary Hazard | 0, 50, or 100 | 250 | 60–90 |
| Extra Hazard | 0, 50, or 100 | 500 | 90-120 |

**(NFPA 13 - Table 11.2.3.1.1) Hose Stream Demand and Water Supply Duration Requirements for Hydraulically Calculated Systems**

## 6- Sprinklers Residual Pressure (NFPA 13 - 11.2.3.1.5)

Minimum operating pressure of any sprinkler shall be 7 psi (0.5 bar).

| Occupancy Classification | Minimum Residual Pressure Required (psi) | Acceptable Flow at Base of Riser (Including Hose Stream Allowance) (gpm) | Duration (minutes) |
|---|---|---|---|
| Light hazard | 15 | 500–750 | 30–60 |
| Ordinary Hazard | 20 | 850–1500 | 60–90 |

(NFPA 13 - Table 11.2.2.1) Water Supply Requirements for Pipe Schedule Sprinkler Systems

For Extra Hazard : it is not mentioned separately but it can be considered in the range **( 30 : 50 ) psi**

## 7- Sprinklers Characteristics (NFPA 13 – 3.6)

- In normal conditions we choose an **Upright standard response** sprinkler with (K=5.6 and Temperature Rating=57 - 77 °C) as it is the common sprinkler for different applications and its not expensive.

- If we are using a suspended ceiling we may use the same characteristics but with Pendent, Recessed, Semi Concealed or Concealed sprinkler.

- In extra hazard or high demand systems we might use the following:-
  - Using high rate sprinkler (K>5.6) with moderate pressure rate Pump. (Low pump cost & High sprinklers cost)

The following are characteristics of a sprinkler that define its ability to control a fire.
(a) Thermal sensitivity.

A measure of the rapidity with which the thermal element operates as installed in a specific sprinkler or sprinkler assembly. One measure of thermal sensitivity is the response time index (RTI) as measured under standardized test conditions.

(1) Sprinklers defined as **fast response** have a thermal element with an RTI of 50 (meters-seconds)$^{1/2}$ or less.
(2) Sprinklers defined as **standard response** have a thermal element with an RTI of 80 (meters-seconds)$^{1/2}$ or more.

(b) Temperature rating.

| Maximum Ceiling Temperature | | Temperature Rating | | Temperature Classification | Color Code | Glass Bulb Colors |
|---|---|---|---|---|---|---|
| °F | °C | °F | °C | | | |
| 100 | 38 | 135–170 | 57–77 | Ordinary | Uncolored or black | Orange or red |
| 150 | 66 | 175–225 | 79–107 | Intermediate | White | Yellow or green |
| 225 | 107 | 250–300 | 121–149 | High | Blue | Blue |
| 300 | 149 | 325–375 | 163–191 | Extra high | Red | Purple |
| 375 | 191 | 400–475 | 204–246 | Very extra high | Green | Black |
| 475 | 246 | 500–575 | 260–302 | Ultra high | Orange | Black |
| 625 | 329 | 650 | 343 | Ultra high | Orange | Black |

(NFPA 13 - Table 6.2.5.1) Temperature Ratings, Classifications, and Color Codings

(c) Orifice size (NFPA13 – 6.2.3.1)

| Nominal K-factor [gpm/(psi)1/2] | K-factor Range [gpm/(psi)1/2] | K-factor Range [dm3/min/(kPa)1/2] | Percent of Nominal K-5.6 Discharge(%) | Thread Type |
|---|---|---|---|---|
| 1.4 | 1.3–1.5 | 1.9–2.2 | 25 | ½ in. NPT |
| 1.9 | 1.8–2.0 | 2.6–2.9 | 33.3 | ½ in. NPT |
| 2.8 | 2.6–2.9 | 3.8–4.2 | 50 | ½ in. NPT |
| 4.2 | 4.0–4.4 | 5.9–6.4 | 75 | ½ in. NPT |
| 5.6 | 5.3–5.8 | 7.6–8.4 | 100 | ½ in. NPT |
| 8.0 | 7.4–8.2 | 10.7–11.8 | 140 | ½ in. NPT or ¾ in. NPT |
| 11.2 | 11.0–11.5 | 15.9–16.6 | 200 | ½ in. NPT or ¾ in. NPT |
| 14.0 | 13.5–14.5 | 19.5–20.9 | 250 | ¾ in. NPT |
| 16.8 | 16.0–17.6 | 23.1–25.4 | 300 | ¾ in. NPT |
| 19.6 | 18.6–20.6 | 27.2–30.1 | 350 | 1 in. NPT |
| 22.4 | 21.3–23.5 | 31.1–34.3 | 400 | 1 in. NPT |
| 25.2 | 23.9–26.5 | 34.9–38.7 | 450 | 1 in. NPT |
| 28.0 | 26.6–29.4 | 38.9–43.0 | 500 | 1 in. NPT |

**(NFPA 13 - Table 6.2.3.1) Sprinkler Discharge Characteristics Identification**

(d) Installation orientation (NFPA13 - 3.6.3)

1-) Flush Sprinkler. A sprinkler in which all or part of the body, including the shank thread, is mounted above the lower plane of the ceiling.

2-) Recessed Sprinkler. A sprinkler in which all or part of the body, other than the shank thread, is mounted within a recessed housing.

3-) Concealed Sprinkler. A recessed sprinkler with cover plates.

4-) Pendent Sprinkler. A sprinkler designed to be installed in such a way that the water stream is directed downward against the deflector.

5-) Sidewall Sprinkler. A sprinkler having special deflectors that are designed to discharge most of the water away from the nearby wall in a pattern resembling one-quarter of a sphere, with a small portion of the discharge directed at the wall behind the sprinkler.

6-) Upright Sprinkler. A sprinkler designed to be installed in such a way that the water spray is directed upwards against the deflector.

(e) Water distribution characteristics (i.e., application rate, wall wetting).
(f) Special service conditions (NFPA13 - 3.6.4)

**1-) Corrosion-Resistant Sprinkler.** A sprinkler fabricated with corrosion-resistant material, or with special coatings or platings, to be used in an atmosphere that would normally corrode sprinklers.

**2-) Dry Sprinkler**. A sprinkler secured in an extension nipple that has a seal at the inlet end to prevent water from entering the nipple until the sprinkler operates.

**3-) Intermediate Level Sprinkler/Rack Storage Sprinkler**. A sprinkler equipped with integral shields to protect its operating elements from the discharge of sprinklers installed at higher elevations.
**4-) Ornamental/Decorative Sprinkler.** A sprinkler that has been painted or plated by the manufacturer.

## 8- Network Pipe Sizing (Seamless Black Steel) (NFPA 13 - 14.5.2.2).

### 1st) Light Hazard:-

| Pipe Size [in] | No. of Sprinklers |
|---|---|
| 1 | 2 |
| 1¼ | 3 |
| 1½ | 5 |
| 2 | 10 |
| 2½ | 30 |
| 3 | 60 |
| 3½ | 100 |

**(NFPA 13 - Table 14.5.2.2.1) Light Hazard Pipe Schedules**

| Pipe Size [in] | No. of Sprinklers |
|---|---|
| 1 | 2 |
| 1¼ | 4 |
| 1½ | 7 |
| 2 | 15 |
| 2½ | 50 |

**(NFPA 13 - Table 14.5.2.4) Number of Sprinklers Above and Below a Ceiling**

### 2nd) Ordinary Hazard:-

| Pipe Size [in] | No. of Sprinklers |
|---|---|
| 1 | 2 |
| 1¼ | 3 |
| 1½ | 5 |
| 2 | 10 |
| 2½ | 20 |
| 3 | 40 |
| 3½ | 65 |
| 4 | 100 |
| 5 | 160 |
| 6 | 275 |

**(NFPA 13 - Table 14.5.3.4) Ordinary Hazard Pipe Schedule**

| Pipe Size [in] | No. of Sprinklers |
|---|---|
| 2½ | 15 |
| 3 | 30 |
| 3½ | 60 |

**(NFPA 13 - Table 14.5.3.5) Number of Sprinklers — Greater than 12-ft (3.7-m) Separations**

| Pipe Size [in] | No. of Sprinklers |
|---|---|
| 1 | 2 |
| 1¼ | 4 |
| 1½ | 7 |
| 2 | 15 |
| 2½ | 30 |
| 3 | 60 |

**(NFPA 13 - Table 14.5.3.7) Number of Sprinklers Above and Below a Ceiling**

### 3rd)Extra Hazard Occupancies:-

Extra hazard occupancies shall be hydraulically calculated.

## 9- Sprinklers Distribution and Network Piping.

### System Protection Area Limitations (NFPA 13 – 8.2).

- The maximum floor area on any one floor to be protected by sprinklers supplied by any **one sprinkler system riser** or combined system riser shall be as follows:

| No. | Hazard | Maximum Area per one Riser | |
|---|---|---|---|
| | | $ft^2$ | $m^2$ |
| 1 | Light hazard | 52,000 | 4831 |
| 2 | Ordinary hazard | 52,000 | 4831 |
| 3 | Extra hazard | | |
| 3.a | Pipe schedule | 25,000 | 2323 |
| 3.b | Hydraulically calculated | 40,000 | 3716 |
| 4 | Storage-High-piled storage | 40,000 | 3716 |

Notes:-

1. The floor area occupied by mezzanines shall not be included in the area limitation.
2. Where single systems protect extra hazard, high-piled storage, or storage covered by other NFPA standards, and ordinary or light hazard areas, the extra hazard or storage area coverage shall not exceed the floor area specified for that hazard and the total area coverage shall not exceed 52,000 $ft^2$ (4831 $m^2$).

### System Requirements:-

2. Each separated zone should be controlled by separated zone control station that consists of :-
   - OS&Y Gate Valve
   - Swing Check Valve
   - Flow or Pressure Switch
   - Test and Drain assembly
   - Air Vent
3. Piping should be schedule 40 black seamless steel.
4. Pipe sizing should be according to the system hazard and according to NFPA tables.

### Sprinkler Distribution Steps:-

1. Locate sprinklers according to its type and maximum spacing and protection areas.
2. Connect sprinklers by single lines according to the chosen network shape (Loop-Grid-Tree)
3. Size the pipes according to sizing tables or for extra hazard according to hydraulic calculations.
4. Locate the zone control stations and their sizes.

### Required Pipe Schedule :-

For seamless black steel $\sigma = 200 MPa$

$$\sigma = \frac{PD}{2t} \rightarrow \boxed{t = \frac{PD}{2\sigma}}$$

## 10-Hydraulic Calculations Procedures (NFPA 13 – 14.4).

The purpose of hydraulic calculations is to calculate the pump required pressure and discharge in order to minimize the cost and achieve the required function.

**Definitions:-**

A : Area of sprinklers operation ($m^2$).
L : Length of Sprinklers Operation Area (m).
W : Width of Sprinklers Operation Area (m).
a : Sprinkler's protection area ($m^2$).
d : Minimum Desired Density ($gpm/ft^2$).
S : Sprinklers Spacing (m).
N : No. of Sprinklers per branch.
$Q_{sp}$: Sprinkler's discharge (gpm).
$Q_h$ : Hose Flow (gpm).
P : Sprinkler's Minimum Residual Pressure (psi).
D : Actual Pipe **Inner** Diameter (in).
C : Hazen-Williams Coefficient = 120 for seamless black steel.

**Steps:-**

1. We have chosen the area of operation (A) and Density (d) from area density curve according to system hazard.
2. Locate the most remote area from the pump (it should be in the highest Sprinkler protected floor.)
3. Calculate the maximum number of sprinklers per branch $N = \frac{1.2\sqrt{A}}{S}$

   Any fractional sprinkler shall be carried to the next higher whole sprinkler.
4. Consider the length of the operation area (L) equal to the length of maximum number of sprinklers per branch.
5. $W = \frac{A}{L}$
6. Draw the area of operation on the located most remote area.
7. Locate the HMD (Hydraulically most demand) Sprinkler where the calculations shall begin.
8. In combined systems at least one hose should be added to the calculations (we chose the nearest hose to the most remote area).
9. To calculate the sprinkler's discharge coefficient (K-Factor) we use the selected HMD sprinkler and its actual spacing and chosen residual pressure.

   $$a = S^2$$

   $$Q_{sp} = a * d$$

   $$Q_{sp} = K\sqrt{P} \rightarrow K = \frac{Q_{sp}}{\sqrt{P}}$$
10. Fix the calculated K-Factor to the nearest value in the K-Factors mentioned table.
11. Re-Calculate the sprinkler's discharge according to the new K-Factor

    $$Q_{sp} = K\sqrt{P}$$

12. Draw a schematic diagram for the system where a Pipe section starts and ends at fittings or valves or sprinklers or hoses showing :-
    - The water path from pump room to the most remote area including all sprinklers in mentioned area and at least on hose.
    - Lengths of each pipe section.
    - Size of each pipe sections.
    - Elevation of each node in the system.

13. The Required Pump Head is $H = H_{EL} + H_{RES} + H_F$
    - $H_{EL}$ : Elevation Head.
    - $H_{RES}$ : HMD Sprinkler Residual Pressure.
    - $H_F$ : HMD Path Friction Loss.

14. The Required Discharge Consists of :-
    - Most Remote Area Sprinklers Discharge
    - Nearest Hose Discharge.

15. Calculations starts at the HMD sprinkler as follows:-
    - P : selected from NFPA tables according to hazard.
    - $Q_{sp} = K\sqrt{P}$
    - Pressure loss in each section is calculated according to Hazen-Williams formula for each pipe diameter and each flow.
      $$P_{loss}(psi) = \frac{4.52 * Q^{1.85}}{C^{1.85} * D^{4.87}} * L(ft)$$
    - Fittings shall be expressed in meanings of equivalent lengths and shall be added to the pipe length before using Hazen-Williams formula.
    - Do not include fitting loss for straight-through flow in a tee or cross.
    - Subtract or add the level difference pressure between the sprinkler's orifice and the main line from the water pressure at this node and between any two points in the system.
    - Calculate each sprinkler discharge according to the water pressure at its discharge node.
    - In each section add the sprinklers discharges or hose discharge that is supplied by such section.

16. In a combined system if the required pressure by the operation area of sprinkler system is less than **100 psi** or the required flow is less than **1250 gpm** then we shall use fire hose required pressure and discharge as follows (NFPA 14 - 5.9.1.1):-
    - Each hose connection require **250 gpm**.
    - Use **2** connections at the most remote standpipe, that requires **500 gpm**.
    - Use **1** connection at each additional stand pipe in the system and that requires **250 gpm**.
    - The total flow not to exceed **1250 gpm**.
    - The pressure required at the most remote hose connection is **100 psi** or **65 psi** if approved by Civil Defense authority (NFPA 14 - 5.7).
    - The pipe sizing shall be 3" for 1 hose, 4" for 2 hoses and 6" for more than 2 hoses.
    - The flow rate required for the standpipe demand of a combined system in a building protected throughout by an automatic sprinkler system shall not be required to exceed **1000 gpm**. (NFPA 14 - 5.9.1.3.1).

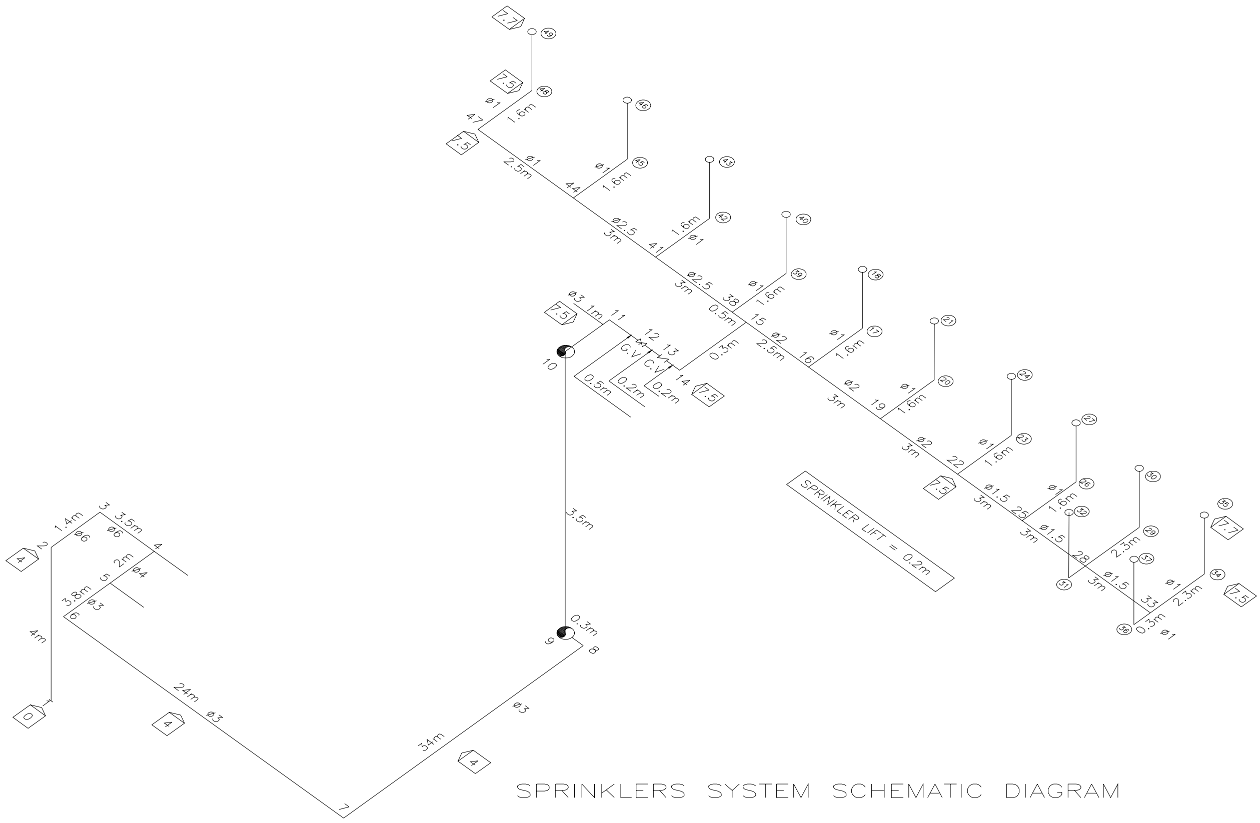
# Hydraulic Calculations Example :-

The example we have here is a VolksWagen car maintenance center.

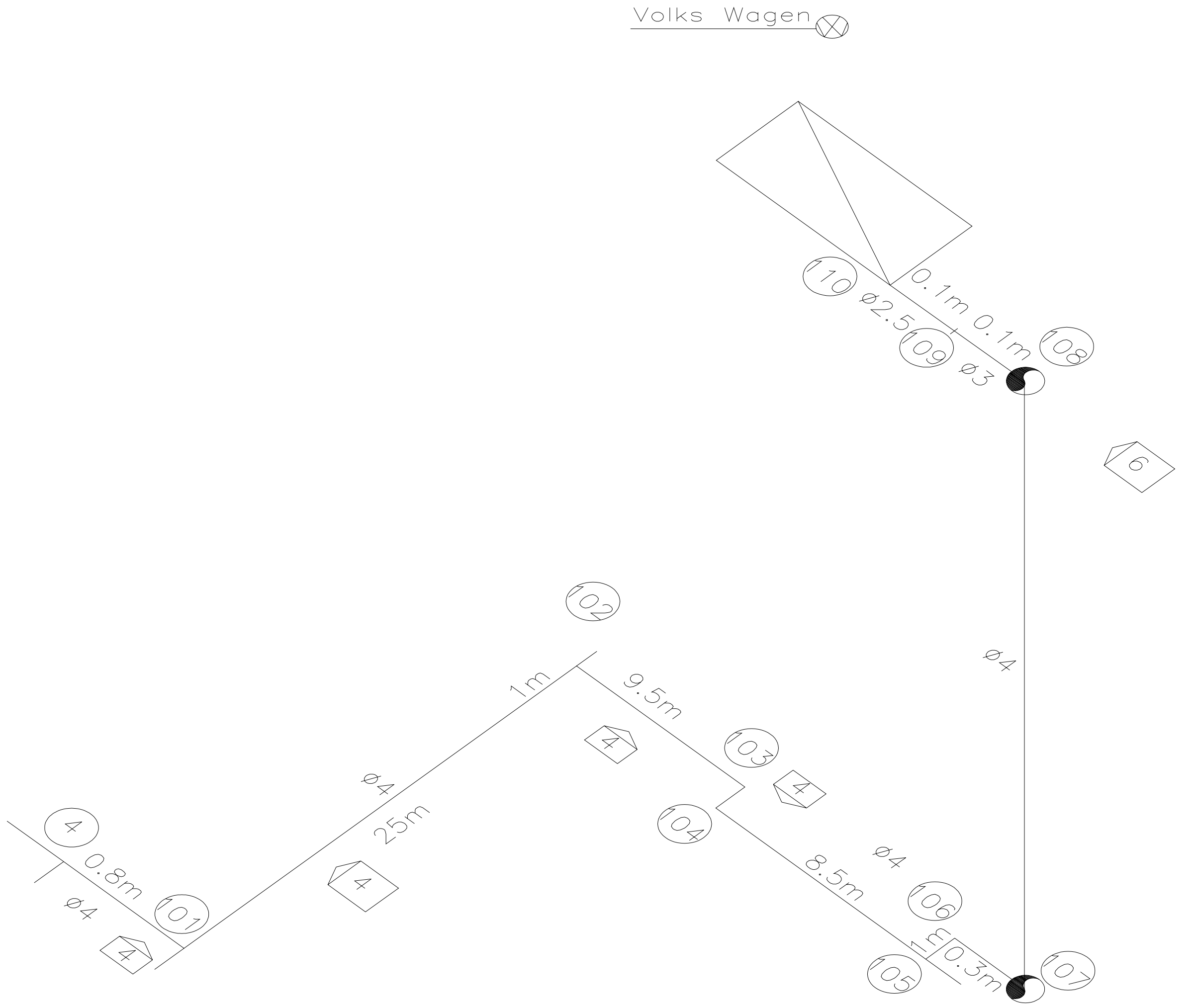
## 1. Hydraulic Calculations Parameters:

| | | |
|---|---|---|
| Hazard : Repair Garages | Ordinary (Group 2) | NFPA 13 A-5-3-2 |
| Minimum Desired Density | 0.2 gpm/ft$^2$ | NFPA 13 11-2-3-1-5 |
| Area of Sprinklers Operation | 1500 ft$^2$ = 139 m$^2$ | NFPA 13 11-2-3-1-5 |
| Minimum Residual Pressure | 20 psi | NFPA 13 11-2-2-1 |
| Fire Hose Discharge | 100 gpm | NFPA 13 11-2-3-1-1 |
| Fire Fighting Duration | 60-90 min | NFPA 13 11-2-3-1-1 |
| Maximum Sprinkler Spacing | 4.6 m = 15 ft | NFPA13 8.6.2.2.1(b) |
| Maximum Area protected by Sprinkler | 12.1 m$^2$ = 130 ft$^2$ | NFPA13 8.6.2.2.1(b) |
| Actual Sprinkler Spacing | 3 m | |
| Actual Area protected by Sprinkler | 9 m$^2$ = 96.88 ft$^2$ | |
| Sprinklers Type | Standard Spray Upright | |
| Temperature Rating | Ordinary (68$^o$C) | |
| Max No. of Sprinklers per Branch | $N = \frac{1.2\sqrt{A}}{S} = \frac{1.2\sqrt{139}}{3} = 4.72 \approx 5$ | |
| Applying the Area of Operation On the most Remote area leads to :- | | |
| No. of most remote Sprinklers | 12 | |
| Remote Sprinkler's Discharge | $Q_{sp}$ = d*a = 0.2*96.88 =19.4 gpm | |
| Calculated Sprinkler's Discharge Coefficient | K=(Q/$\sqrt{P}$ )=(19.4/$\sqrt{20}$ ) = 4.34 gpm/psi$^{1/2}$ | |
| Actual Discharge Coefficient | K = 5.6 gpm/psi$^{1/2}$ | NFPA 13 6.2.3.1 |
| Sprinkler's Orifice Size | ½ in. NPT | NFPA 13 6.2.3.1 |
| Pipe Sizing | | NFPA 13 14.5.3.4 |

## 2. System Schematic Diagrams:-




SPRINKLERS SYSTEM SCHEMATIC DIAGRAM




STAND PIPE SYSTEM SCHEMATIC DIAGRAM

## 3. Hydraulic Calculations Sheet:-

| Section | Flow [gpm] | Pipe Size [in] | Fittings& Devices | Pipe Equiv. Length [ft] | Friction loss [psi/ft] | Required [psi] | Elev [m] | Notes. |
|---|---|---|---|---|---|---|---|---|
| SP No. 35 | q 25 | | Elbow 90 | LGTH. 0.656 | | PT. 20 | | $Q_{sp}=K\sqrt{P}$=5.6 |
| From. 35 | Q 25 | 1.049" | | FTG. 2 | 0.197 | PF. +0.523 | | $\sqrt{20}$ = 25.044 |
| To. 34 | | | | TOT. 2.656 | | PE. +0.284 | -0.2 | |
| SP No. | q 25 | | Tee | LGTH. 7.55 | | PT. 20.81 | | |
| From. 34 | Q 25 | 1.049" | | FTG. 5 | 0.197 | PF. +2.472 | | |
| To. 33 | | | | TOT. 12.55 | | PE. | | |
| SP No. | q 25.9 | | Tee | LGTH. 0.98 | | PT. 23.28 | | Assume const |
| From. 33 | Q 50.9 | 1.049" | | FTG. 5 | 0.197 | PF. -1.178 | | friction loss |
| To. 36 | | | | TOT. 5.98 | | PE. | | [psi/ft] |
| SP No. 37 | q 25.9 | | Elbow 90 | LGTH. 0.656 | | PT. 22.1 | | $Q_{sp}=K\sqrt{P}$=5.6* |
| From. 36 | Q 50.9 | 1.049" | | FTG. 2 | 0.197 | PF. -0.523 | | $\sqrt{21.3}$ =25.85 |
| To. 37 | | | | TOT. 2.656 | | PE. -0.284 | +0.2 | |
| SP No. | q 50.9 | | | LGTH. 9.84 | | PT. 23.28 | | |
| From. 33 | Q 50.9 | 1.61 " | | FTG. | 0.091 | PF. +0.9 | | |
| To. 28 | | | | TOT. 9.84 | | PE. | | |
| SP No. | q 25.6 | | Tee | LGTH. 7.55 | | PT. 24.2 | | Assume const |
| From. 28 | Q 76.5 | 1.049" | | FTG. 5 | 0.197 | PF. -2.47 | | friction loss |
| To. 29 | | | | TOT. 12.55 | | PE. | | [psi/ft] |
| SP No. 30 | q 25.6 | | Elbow 90 | LGTH. 0.656 | | PT. 21.73 | | $Q_{sp}=K\sqrt{P}$=5.6* |
| From. 29 | Q 76.5 | 1.049" | | FTG. 2 | 0.197 | PF. -0.523 | | $\sqrt{20.92}$ =25.61 |
| To. 30 | | | | TOT. 2.656 | | PE. -0.284 | +0.2 | |
| SP No. | q 26.4 | | Tee | LGTH. 0.98 | | PT. 24.2 | | Assume const |
| From. 28 | Q 102.9 | 1.049" | | FTG. | 0.197 | PF. -1.18 | | friction loss |
| To. 31 | | | | TOT. 5.98 | | PE. | | [psi/ft] |
| SP No. 32 | q 26.4 | | Elbow 90 | LGTH. 0.656 | | PT. 23.02 | | $Q_{sp}=K\sqrt{P}$=5.6* |
| From. 31 | Q 102.9 | 1.049" | | FTG. 2 | 0.197 | PF. -0.523 | | $\sqrt{22.2}$ =26.39 |
| To. 32 | | | | TOT. 2.656 | | PE. -0.284 | +0.2 | |
| SP No. | q 102.9 | | | LGTH. 9.84 | | PT. 24.2 | | |
| From. 28 | Q 102.9 | 1.61 " | | FTG. | 0.334 | PF. +3.29 | | |
| To. 25 | | | | TOT. 9.84 | | PE. | | |
| SP No. | q 28 | | Tee | LGTH. 5.25 | | PT. 27.49 | | Assume const |
| From. 25 | Q 130.9 | 1.049" | | FTG. 5 | 0.197 | PF. -2.02 | | friction loss |
| To. 26 | | | | TOT. 10.25 | | PE. | | [psi/ft] |
| SP No. 27 | q 28 | | Elbow 90 | LGTH. 0.656 | | PT. 25.47 | | $Q_{sp}=K\sqrt{P}$=5.6* |
| From. 26 | Q 130.9 | 1.049" | | FTG. 2 | 0.197 | PF. -0.523 | | $\sqrt{24.96}$ =27.97 |
| To. 27 | | | | TOT. 2.656 | | PE. -0.284 | +0.2 | |
| SP No. | q 130.9 | | | LGTH. 9.84 | | PT. 27.49 | | |
| From. 25 | Q 130.9 | 1.61 " | | FTG. | 0.522 | PF. +5.14 | | |
| To. 22 | | | | TOT. 9.84 | | PE. | | |
| SP No. | q 30.6 | | Tee | LGTH. 5.25 | | PT. 32.63 | | Assume const |
| From. 22 | Q 161.5 | 1.049" | | FTG. 5 | 0.197 | PF. -2.02 | | friction loss |
| To. 23 | | | | TOT. 10.25 | | PE. | | [psi/ft] |
| SP No. 24 | q 30.6 | | Elbow 90 | LGTH. 0.656 | | PT. 30.61 | | $Q_{sp}=K\sqrt{P}$=5.6* |
| From. 23 | Q 161.5 | 1.049" | | FTG. 2 | 0.197 | PF. -0.523 | | $\sqrt{29.83}$ =30.6 |
| To. 24 | | | | TOT. 2.656 | | PE. -0.284 | +0.2 | |
| SP No. | q 161.5 | | | LGTH. 9.84 | | PT. 32.63 | | |
| From. 22 | Q 161.5 | 2.067" | | FTG. | 0.228 | PF. +2.24 | | |
| To. 19 | | | | TOT. 9.84 | | PE. | | |
| SP No. | q 31.7 | | Tee | LGTH. 5.25 | | PT. 34.87 | | Assume const |
| From. 19 | Q 193.2 | 1.049" | | FTG. 5 | 0.197 | PF. -2.02 | | friction loss |
| To. 20 | | | | TOT. 10.25 | | PE. | | [psi/ft] |
| SP No. 21 | q 31.7 | | Elbow 90 | LGTH. 0.656 | | PT. 32.85 | | $Q_{sp}=K\sqrt{P}$=5.6* |
| From. 20 | Q 193.2 | 1.049" | | FTG. 2 | 0.197 | PF. -0.523 | | $\sqrt{32.04}$ =31.7 |
| To. 21 | | | | TOT. 2.656 | | PE. -0.284 | +0.2 | |
| SP No. | q 193.2 | | | LGTH. 9.84 | | PT. 34.87 | | |
| From. 19 | Q 193.2 | 2.067" | | FTG. | 0.318 | PF. +3.13 | | |
| To. 16 | | | | TOT. 9.84 | | PE. | | |
| SP No. | q 33.2 | | Tee | LGTH. 5.25 | | PT. 38 | | Assume const |
| From. 16 | Q 226.4 | 1.049" | | FTG. 5 | 0.197 | PF. -2.02 | | friction loss |
| To. 17 | | | | TOT. 10.25 | | PE. | | [psi/ft] |
| SP No. 18 | q 33.2 | | Elbow 90 | LGTH. 0.656 | | PT. 35.98 | | $Q_{sp}=K\sqrt{P}$=5.6* |
| From. 17 | Q 226.4 | 1.049" | | FTG. 2 | 0.197 | PF. -0.523 | | $\sqrt{35.17}$ =33.21 |
| To. 18 | | | | TOT. 2.656 | | PE. -0.284 | +0.2 | |
| SP No. | q 226.4 | | Tee | LGTH. 8.2 | | PT. 38 | | |
| From. 16 | Q 226.4 | 2.067" | | FTG. 10 | 0.426 | PF. +7.75 | | |
| To. 15 | | | | TOT. 18.2 | | PE. | | |
| | | | | | | | | |
| Section | Flow | Pipe | Fittings& | Pipe Equiv. | Friction | Required | Elev | Notes. |

| | [gpm] | Size [in] | Devices | Length [ft] | loss [psi/ft] | [psi] | [m] | |
|---|---|---|---|---|---|---|---|---|
| SP No. | q 354.4 | 3.068" | Elbow 90 | LGTH. 0.98 | 0.143 | PT. 45.75 | | Assume $Q_{av}$=30gpm $Q_{tot}$=226.4+(4*32 ) =354.4 gpm |
| From. 15 | Q 354.4 | | | FTG. 7 | | PF. +1.14 | | |
| To. 14 | | | | TOT. 7.98 | | PE. | | |
| SP No. | q 354.4 | 3.068" | Check Valve | LGTH. 0.66 | 0.143 | PT. 46.89 | | |
| From. 14 | Q 354.4 | | | FTG. 16 | | PF. +2.38 | | |
| To. 13 | | | | TOT. 16.66 | | PE. | | |
| SP No. | q 354.4 | 3.068" | Gate Valve | LGTH. 0.66 | 0.143 | PT. 49.27 | | |
| From. 13 | Q 354.4 | | | FTG. 1 | | PF. +0.24 | | |
| To. 12 | | | | TOT. 1.66 | | PE. | | |
| SP No. | q 354.4 | 3.068" | Elbow 90 | LGTH. 1.64 | 0.143 | PT. 49.51 | | |
| From. 12 | Q 354.4 | | | FTG. 7 | | PF. +1.24 | | |
| To. 11 | | | | TOT. 8.64 | | PE. | | |
| SP No. | q 354.4 | 3.068" | Tee | LGTH. 3.28 | 0.143 | PT. 50.75 | | |
| From. 11 | Q 354.4 | | | FTG. 15 | | PF. +2.61 | | |
| To. 10 | | | | TOT. 18.28 | | PE. | | |
| SP No. | q 354.4 | 3.068" | Tee | LGTH. 9.84 | 0.143 | PT. 53.36 | | |
| From. 10 | Q 354.4 | | | FTG. 15 | | PF. +3.55 | | |
| To. 9 | | | | TOT. 24.84 | | PE. +4.98 | -3.5 | |
| SP No. | q 354.4 | 3.068" | Elbow 90 | LGTH. 0.98 | 0.143 | PT. 61.89 | | |
| From. 9 | Q 354.4 | | | FTG. 7 | | PF. +1.14 | | |
| To. 8 | | | | TOT. 7.98 | | PE. | | |
| SP No. | q 354.4 | 3.068" | Elbow 90 | LGTH. 111.55 | 0.143 | PT. 63.03 | | |
| From. 8 | Q 354.4 | | | FTG. 7 | | PF. +16.95 | | |
| To. 7 | | | | TOT. 118.55 | | PE. | | |
| SP No. | q 354.4 | 3.068" | Elbow 90 | LGTH. 78.74 | 0.143 | PT. 79.98 | | |
| From. 7 | Q 354.4 | | | FTG. 7 | | PF. +12.26 | | |
| To. 6 | | | | TOT. 85.74 | | PE. | | |
| SP No. | q 354.4 | 3.068" | | LGTH. 12.47 | 0.143 | PT. 92.24 | | |
| From. 6 | Q 354.4 | | | FTG. | | PF. +1.78 | | |
| To. 5 | | | | TOT. 12.47 | | PE. | | |
| SP No. | q 354.4 | 4.026" | Tee | LGTH. 6.56 | 0.038 | PT. 94.02 | | |
| From. 5 | Q 354.4 | | | FTG. 20 | | PF. +1.01 | | |
| To. 4 | | | | TOT. 26.56 | | PE. | | |
| SP No. | q 454.4 | 6.065" | Tee | LGTH. 11.48 | 0.008 | PT. 95.03 | | |
| From. 4 | Q 454.4 | | | FTG. 30 | | PF. +0.33 | | |
| To. 3 | | | | TOT. 41.48 | | PE. | | |
| SP No. | q 454.4 | 6.065" | Elbow 90 | LGTH. 4.6 | 0.008 | PT. 95.36 | | |
| From. 3 | Q 454.4 | | | FTG. 14 | | PF. +0.15 | | |
| To. 2 | | | | TOT. 18.6 | | PE. | | |
| SP No. | q 454.4 | 6.065" | | LGTH. 16.4 | 0.008 | PT. 95.51 | | |
| From. 2 | Q 454.4 | | | FTG. | | PF. +0.13 | | |
| To. 1 | | | | TOT. 16.4 | | PE. +5.69 | -5 | |
| | Q 454.4 gpm | | | | PT. 101.33 psi | | | |



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